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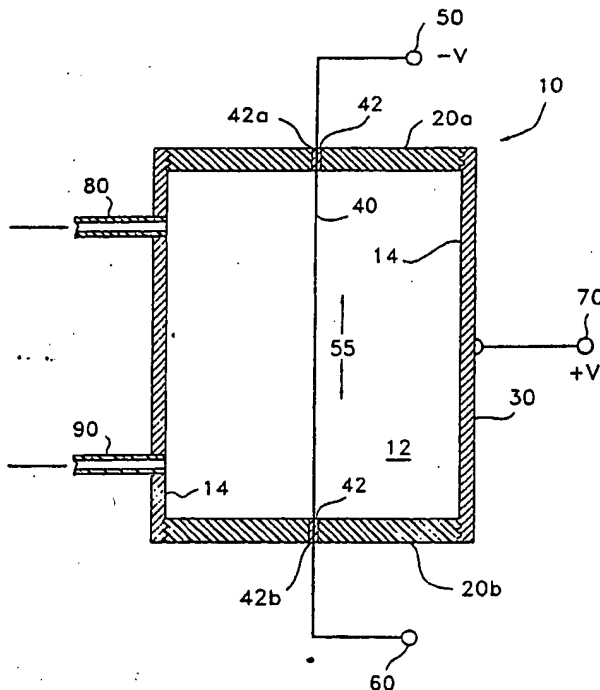
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(54) Title: GLOW DISCHARGE APPARATUS AND METHODS PROVIDING PREREQUISITES AND TESTING FOR NUCLEAR REACTIONS

(57) Abstract

A method and apparatus for experimenting and testing cold fusion or other solid state nuclear reaction processes by means of achieving high pressures of solubilized light fusion elements in solid metal lattices from the gas phase. The apparatus uses an anode (70) and cathode (50) positioned in a chamber (12) receptive of the fusion element gases to produce controlled conditions compatible with postulated cold fusion for laboratory and reactor purposes. Two electrode (40) embodiments are disclosed for use in a glow discharge mode of operation. The electrodes (40) are thoroughly scrubbed of impurities by heating and sputtering prior to experimenting on cold fusion processes. The results of cold fusion experimentation are then monitored and controlled.



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**GLOW DISCHARGE APPARATUS AND METHODS
PROVIDING PREREQUISITES AND TESTING FOR NUCLEAR
REACTIONS**

CONTINUITY

This application is a CONTINUATION-IN-PART of a U.S. Patent Application serial number 07/967,911 filed October 28, 1992, and entitled AN APPARATUS AND METHOD FOR ACHIEVING HIGH PRESSURES OF SOLUBILIZED LIGHT ELEMENTS IN SOLID METAL LATTICES FROM THE GAS PHASE BY USE OF GLOW DISCHARGE ELECTRODES FOR THE PURPOSES OF ACHIEVING NUCLEAR FUSION, which is a CONTINUATION of U.S. Patent Application serial number 07/341,150 filed April 20, 1989, entitled AN APPARATUS AND METHOD FOR ACHIEVING HIGH PRESSURES OF SOLUBILIZED LIGHT ELEMENTS IN SOLID METAL LATTICES FROM THE GAS PHASE BY USE OF GLOW DISCHARGE ELECTRODES FOR THE PURPOSES OF ACHIEVING NUCLEAR FUSION, the disclosures of which are specifically incorporated herein.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to methods and apparatus used in the creation of an environment for generating and evaluating postulated nuclear reactions for the purposes of generating energy and producing nuclear reaction formed by-products. In particular, the present invention pertains to an apparatus for conducting cold fusion experiments in order to evaluate the postulated nuclear processes and components, for controlling postulated cold fusion reactions, and for the potential production of and testing for usable energy output obtained from the glow discharge treatment of fusion lattice metals.

2. Statement of the Problem

To date, only nuclear fission reactions have been harnessed for the production of energy and isotopes. During one mode of nuclear fission, U-235 or plutonium

atoms, fission or split releasing neutrons that catalyze further fissions to release heat energy or are absorbed in a moderator. However, nuclear fission reactors are immensely expensive, generate more than one hundred fission by-products (all highly radioactive and generally undesirable, creating ever increasing waste disposal problems) and generate far less watts per pound of fuel than can be obtained in fusion reactions.

In fusion reactions, however, light elements and isotopes of light elements are combined at a nuclear level to make heavier elements. As heavier elements are created, there is a net loss of mass. When lost mass is totally converted into energy, the energy can be calculated from Einstein's equation

$$E=mc^2$$

Formula 1

Where E = Energy

m = Mass in amu

c = Speed of Light

The United States of America has been funding a fusion energy program for nearly forty years with the intent of finding methods to produce power from fusion. After great expenditures, the only method for generating fusion power has been found to be setting off hydrogen bombs underground and then to tap into the heat energy produced. Political and ecological concerns make this method highly unfeasible.

It has recently been reported that when metals such as palladium (Pd) are implanted with light elements such as deuterium in an aqueous electro-chemical environment that neutrons and heat energy are produced with the energy output being eight times greater than the energy input. Fleischmann and Pons, "Electrochemically Induced Nuclear Fusion of Deuterium", J. Electroanal. Chem. 261 (1989) pgs. 301-308 at pg. 305 and "Observation of Cold Nuclear Fusion in Condensed Matter"; by Jones, Palmer, Ciri, Decker, Jensen, Thorne, Taylor, Rafelski, Preprint.

This so-called "cold fusion" may provide a substantially lower-cost approach to the generation of energy in the form of neutrons, gamma rays and heat energy than that provided by conventional nuclear fission reactors. "Cold" in this case means temperatures orders of magnitude below those of the H-bomb which is 50 million degrees.

The aforesaid experiments of Pons and Fleischmann and of Jones and the subsequent confirmations that were reported in the press convey the possibility that cold fusion produces fusion energy. Reportedly, fusion has been produced in solid metal polycrystalline lattices that have been electro-chemically saturated with isotopes of hydrogen and lithium when the metal is used as a cathode in an aqueous solution electrolytic cell containing heavy water and various dissolved metal electrolytes, such as LiOD.

While successful operation of cold fusion apparatus of Pons, Fleischmann, Jones and others would provide a proof of principle for the operation of cold fusion, a definite need exists for a cold fusion reactor that more effectively pumps light fusion elements (FEs) into the fusion lattice metal (FLM) to obtain higher energy outputs. The available fusion elements (FEs) are:

TABLE I
Fusion Elements (FEs)

<u>Nuclear Symbol</u>	<u>Name</u>
^1H	Hydrogen (common)
^2H	Deuterium
^3H	Tritium
^3He	Helium Three
^4He	Helium Four (common)
^5Li	Lithium Five
^6Li	Lithium Six
^7Li	Lithium Seven

In addition to palladium, the following types of fusion lattice metals (FLM) could also potentially be used: titanium, zirconium, vanadium, platinum, thorium, nickel, hafnium, niobium, tantalum, cerium or alloys and mixtures thereof.

Another need exists to provide a test apparatus and empirical experimental design device for use in evaluating and understanding the mechanisms of nuclear fusion as discovered by Pons, Fleischmann, Hawkins; and Jones & Associates that is not aqueous in nature and which energetically inserts the FEs into the FLM.

Pons and Fleischmann also reported an experiment that became uncontrolled. They claim that an amount of the palladium metal rod was vaporized in an explosion. On this basis, a need exists to have absolute control over any cold fusion or other solid state nuclear reaction such that safe shutdown procedures may be employed thereby avoiding any chance of uncontrollable runaway reactions. As an example, solid state nuclear reactions may comprise fission reactions, fusion reactions, or other nuclear interaction.

Furthermore, there are a number of reasons why one might wish to operate such reactors at temperatures other than those where it is practical to operate in aqueous solutions. Operation cannot be maintained at temperatures much below 0°C (273°K) even with the use of anti-freeze in the aqueous solution. Operations at temperatures approaching 500°C become impractical because of the pressures of steam that one must contain and the expense incurred in trying to deal with high temperature, high pressure steam valves, seals, fittings, pumps and containment vessels.

In one proposed reaction that might be generating some or all of the power in such a fusion reactor, a sub-atomic particle called a muon, a particle of cosmic origin, has been suggested by Jones et al. and earlier referenced, as a catalyst for the reaction. It has been suggested that this reaction would work best at 900°C. This temperature is high for the operation of an aqueous reaction chamber. A clear need exists to create a reactor that operates over a wider temperature range than that practically allowed in an aqueous-based reactor.

The cold fusion reactors of the Pons and Fleischmann group are reported to achieve the most power output when using palladium metal. This is an expensive precious metal. Any system that has to use large quantities of the metal will be very expensive to build. For example, the Wall Street Journal, April 17, 1989, pg. B5, speculated that a 600 megawatt thermal station, based upon Pons' electrochemical approach, would require 1,193,662 meters of 0.4 centimeter diameter palladium rods. A need exists for a system that allows use of sparing quantities of the metal which will thereby be a cheaper and more cost-saving system. There is a definite need for a reactor that can use sparing amounts of such precious metals.

As yet, there is no known labeled catalyzing mechanism to make such a cold fusion reaction commence. Whatever it is that catalyzes the observed unexplained nuclear reactions might be short-lived and of a local nature or dependent on lattice energies of FEs. Therefore, there is a postulated need in the experimental forces to provide higher pressures and broader exciting energies of fusion elements in the fusion lattice. It is entirely likely that any of these fusion reactions depend on pressures of the fusion elements (FEs) inside of the fusion lattice metal (FLM). Ability to control energies of FEs within the fusion lattice metal would be more likely to catalyze fusion reactions. There is a definite need for a reactor that operates at a wider tunable range of energies of FEs in the FLMs.

In the experiments of Pons and Fleischmann and those of Jones, it has been reported that the experiments in aqueous solutions experience problems of electrode fouling. This is most likely because of trace atoms adsorbed onto the surface of the palladium metal rods being used. There is a definite need for a system that is either non-fouling, one where any detrimental fouling is cleaned up as the system operates or a system that is not sensitive to any fouling that may exist.

In aqueous cold fusion reactions to date there is no way to preferentially tune to differing balances of nuclear reactions. There is a need to do so, if achievable, to tune the reactor to specific ideal reactions.

The present invention provides solutions to the above recognized needs in the newly discovered process of cold fusion.

3. Status of acceptance of cold fusion and related art

At the time of the filing of this Continuation -in-Part, the United States Patent and Trademark Office has taken the position that a reputable showing of evidence of operability of systems of the type disclosed herein has not been achieved to date. The need for "repeatable results" has been stressed. Further, representatives of the Patent and Trademark Office have also stressed that virtually no one in the scientific community considers the results of cold fusion as being confirmed.

At this same time, some reputable members of the scientific community are reporting repeatable and remarkable evidence of energy releasing activity which has

been generally referred to as cold fusion. (e.g. Kuchеров et. al.. of LUCH, Russia and Claytor of Los Alamos, U.S.A.). World-wide cold fusion activity appears to be increasing rather than decreasing as evidenced by attendance at the Third Annual Cold Fusion Conference in Nagoya, Japan and plans and paper submissions for the Fourth Annual Cold Fusion Conference in Maui, Hawaii.

This current period of active uncertainty between those who contest the existence of cold fusion and those who consider results of current and past experimentation has created a substantial need for apparatus and methods of experimentally determining the viability of initiating and controlling energy related reactions which have been generally designated cold fusion. The inventor recognizes that mechanisms and reactions basic to cold fusion or what is considered to be cold fusion is not currently known. The mechanism may, in fact, comprise some fission activity as well as limited fusion. For this reason, throughout this disclosure, references to cold fusion, should be understood to comprise cold fusion, related fusion reactions and other as yet undefined mechanisms which produce heat, charged particles, alpha particles, beta particles, x-rays, gamma rays, neutrons and other experimentally derived products which are currently only explained by a nuclear reaction. References to solid state nuclear reactions, herein, should be considered to be synonymous with the wider definition of cold fusion described above.

In any event, in the creative environment of current scientific endeavor currently associated with cold fusion, there exists a definite need for test and experimental apparatus and methods as disclosed herein. As well, any success or use of the novel experimental apparatus and methods disclosed herein in proving the reality of cold fusion should yield equally novel apparatus and methods of obtaining and producing cold fusion and related nuclear reactions and by-products.

4. Solution to the Problem

The present invention provides for a novel gas-phase reactor rather than the aqueous reactors of Pons and Jones. Instead of an electrochemical potential being maintained over a cathode in an aqueous ionic solution, a negative electrode is used in a gas-phase glow discharge plasma where low energy ions of the FEs are implanted

into the fusion lattice metal (FLM) electrodes. The terms FE and FLM will be consistently used throughout this disclosure.

The potential available in this low energy implantation can range from 100 to 5000 volts of energy for implantation. Accordingly, Pons and Fleischmann report a potential of 0.8 volt with a suggestion that they might be able to get the potential as high as 2.0 volts. These are potentials that are directly translatable into pressures of FEs within the FLM. What this implies is that the present invention provides for much greater range of energies of implantation of the FE's into the FLM.

The present invention allows for higher mobilities and pressures of the FEs within the FLM. Any nuclear reaction that is sensitive to lattice pressures of solubilized FEs may be boosted in rate by present invention.

The present invention, therefore, provides a simple laboratory test apparatus and empirical testing design fixture for further investigation of solid state nuclear reactions, the nuclear processes involved and the various combinations of the FEs and FLMs, and the nuclear reactions of the FE mixtures that can take place in the FLMs.

In the present invention significant safety control of such solid state nuclear reactions can be increased by using thinner wires or thinner structures of the metal in question. Pressures, temperatures, and mobilities can be cut down in fusion lattice metal by cutting down FE lattice pressure by releasing FEs rapidly from the metal.

Because of increased pressures available, under the teachings of the present invention, energy generation can be produced in smaller and thinner wires and films of the FLM. This allows much higher rates of control over the cold fusion reactions such that safe shutdown procedures may be employed thereby avoiding any chance of uncontrollable runaway reactions.

The present invention allows operation at much higher temperatures, on the order of 900°C by virtue of the use of thin film sheets or fabrications of palladium metal. The melting point of palladium is 1544°C. By virtue of using gas discharge in the present reaction, thin films of the fusion lattice metal may be used. Thin films are able to radiate heat by blackbody radiation and convection or forced gas cooling and to equilibrate quickly due to low thermal mass. Being thinner, the whole FLM can equilibrate to temperatures of the surrounding environment at a rate $\Delta T^\circ/\text{sec}$ which

increases as a function of the inverse proportion of the FLM thickness or radius and proportional to thermal diffusivity of the FLM material. These attributes could not be provided in an aqueous based reactor. The present invention provides, therefore, for the use of smaller amounts of FLM to achieve cold fusion then required for electrochemical approaches with higher faster heat emissivity per unit of FLM material.

The present invention does not experience the problems of surface fouling for two separate reasons. First, ions of the FEs are implanted at a low energy into the fusion lattice metal through use of glow discharge. This is because the FE atoms have been ionized in the discharge dark space over the metal surface and have picked up energies in the range of slightly over 0 ev to as high as 3 Kev and are accelerated in that electric field as is well understood in the art of glow discharge. This allows these accelerated ions, some of which may be recombined with electrons which arrive at the cathode surface as neutral atoms, to implant themselves into the metal surface to a depth of a number of atomic layers. Being light elements the ions travel at high velocities and have high penetration ability. This means that even if the surface of the element was fouled with some coating of non-FE absorbed atoms, the fusion elements would be able to pierce this layer. Secondly, allowing for a small amount of noble gas (i.e., neon or argon) within the gas mixture in the reactor canister provides a small amount of sputtering. Such sputtering keeps FLM surfaces relatively free of adatoms. Under the teachings of the present invention a thorough cleaning of the fusion elements and of the system components eliminates harmful activity or deposition of impurities from the system.

The present invention solves a number of problems over the prior approaches as clearly described in the details of the present invention provided hereafter.

SUMMARY OF THE INVENTION

A system for testing and evaluating nuclear cold processes is disclosed. In addition said system comprises apparatus and is used with methods which may usefully produce a solid state nuclear reaction in addition and providing for such testing and evaluation. The system comprises a canister having a hermetically sealed

chamber containing one or a plurality of cathodes with each cathode composed of a fusion lattice metal (FLM) and one or a plurality of anodes composed of fusion lattice metal or other suitable metal. A gas composed of a fusion element (FE) is injected into the system at a predetermined pressure and temperature and the cathode and anode are supplied for a long enough time with sufficient electrical power to maintain a sustained glow discharge condition for the cathodes. It is postulated that fusion initiates after these parameters have been satisfied.

In one embodiment, the system of the present invention is postulated to achieve highest efficiency when current density at the cathode is sufficient to obtain and maintain an abnormal glow discharge. A multiple electrode power generating mode is designed to deliver power continuously while maintaining an ability to expel and thereby harvest salable fusion isotope products.

In another embodiment, a simple test canister for conducting research into the nature of the nuclear fusion processes involved and the use of different types and combinations of FEs and FLMS is provided wherein a coaxial chamber has an anode located in the cylindrical sidewalls and a cathode axially located therein with FE gas being injected in the region there between.

BRIEF DESCRIPTION OF THE DRAWING

FIGURE 1 is a cross-sectional view of a first embodiment of a canister of the present invention;

FIGURE 2 is a block diagram showing the electrical and gas connections to the canister of Figure 1;

FIGURE 3 is a block diagram of the system of the present invention in operation under shutdown feedback control;

FIGURE 4 is a modified related art graph of the ratio of resistance R of an FE solubilized lattice metal to the resistance R_0 of the FE deficient FLM versus a typical relative time scale for glow discharging FLMS;

FIGURES 5a and 5b are the top and oblique views of an FLM wire or rod showing current density J out from the surface for maintaining glow discharge and showing magnetic field B for increasing ionizing efficiencies;

FIGURE 6 sets forth a first three electrode embodiment of the canister of the present invention;

FIGURE 7a is a modified related art graph of the cathode voltage drop V_c near the surface of the cathode when glow discharge exists;

FIGURE 7b is a related art map of typical space charge densities during normal glow discharge;

FIGURE 8 sets forth a related art lattice modified to show an ion of FE gas accelerated by the electric field E_c of the cathode potential drop, V_c implanting itself into the FE matrix with an energy in electron volts (ev) equal to that amount of cathode field drop in volts (V_c) that it passed through while ionized to a +1 electron charge unit (this is the case for hydrogen, tritium and deuterium);

FIGURE 9 is a related art graph showing the relation between relative cathode-drop thickness and cathode drop of potential;

FIGURE 10 is a related art illustration of the mechanism of sputtering;

FIGURE 11 is the related art lattice of Figure 8 modified to illustrate the action of the reversed (minus rather than plus) space charge field in fast negative coefficient of reactivity control on the release of FEs on attainment of thermionic emission temperatures;

FIGURE 12 is a cross-sectional view of an embodiment of a canister which is similar to the canister of Figure 1;

FIGURE 13 is a cross-sectional view of an embodiment of a canister which is similar to the canister of Figure 12; and

FIGURE 14 sets forth a second three electrode embodiment of the canister of the present invention.

DETAILED SPECIFICATION

The present invention utilizes a non-aqueous method for saturating FLM (such as palladium) with deuterium and other light elements and light elemental isotopes directly from the gas phase by using the FLMs as cathodes in a gas glow discharges environment. By using gas glow discharge, as is known in sputtering art, higher energies are available for bombarding FLM surfaces than energies available in a wet

cell. Also, as is well understood by one skilled in the glow discharge art, the glow discharge of the present invention allows FEs (especially hydrogen isotopes) to be pumped into the FLM at a higher energy thereby allowing greater pressures of hydrogen in the lattice in order to increase the rate of any solid state nuclear reaction energy output.

The use of glow discharge creates small amounts of sputtering at the metal surface of the crystal lattice. Small amounts of noble gases are added to the FE gas, thereby removing small amounts of adsorbed surface atoms and small amounts of the FLM itself. This sputtering provides a continuous cleaning activity which eliminates decreased diffusivities created by surface fouling which is created by adsorption of atom impurities.

Since the present invention operates in a gas phase, it is capable of possibly generating and then testing for nuclear reactions in a much larger temperature range of the FLM than would be allowed when operating in aqueous solutions.

The following represents the disclosure of inventive apparatus and methods based upon scientific principle understood by those skilled in the art. Reference is now made to the embodiments illustrated in Figures 1-14 wherein like numerals are used to designate like parts throughout.

1. Simple Coaxial Gas Reactor

In Figure 1, the gas canister 10 of the present invention is shown of approximately 5 inches in diameter and 8 inches in height. The canister 10 comprises electrically insulating hermetically sealed caps 20 made of vacuum compatible machinable high-temperature ceramic at both ends of a cylindrical metal wall 30. A palladium electrode 40 is axially centered in the canister 10 to make a co-axial arrangement with the cylinder wall 30. Electrode 40 may be a wire, a rod, or a coating of palladium or other FLM or alloy thereof. Substrate material for electrode 40 may include titanium, vanadium, zirconium, platinum, thorium, nickel, hafnium, niobium, tantalum, cerium, copper, silver or mixtures and alloys thereof. Lithium, rare earth metals or semiconducting elements may be added in small amounts to adjust d-orbital band-gap energies. A preferred embodiment is cast wires or rods that

have been annealed. A negative voltage is applied to terminal 50. A palladium or palladium covered electrode 40 is provided between terminals 50 and 60 which is delivered out from the canister 10. A third terminal 70 is connected to the cylindrical metal canister to which positive voltage is provided. In one mode of operation, terminal 50 (and, therefore wire 40) is the CATHODE and terminal 70 (and, therefore wall 30) is the ANODE. An inlet port 80 is provided as well as an outlet port 90. It is to be understood that the +V could be at ground potential and, therefore, gas recirculation loop connections 80 and 90 could also be at ground. Or, the connections 80 and 90 could likewise be insulated from the canister 10.

In the preferred embodiment, the canister 10 contains a chamber 12 which is hermetically sealed and which is capable of withstanding internal pressures of 0.01 microns up to 10 atmospheres. The electrode 40, in the preferred embodiment, is typically a cylindrical cast wire or rod in the range of 0.001 inch to 1 inch, but with a preference toward diameters in the 0.050 inch range to increase speed of control of pressures of FEs in the lattice, as will be subsequently discussed.

In the preferred embodiment, the anode or cylindrical wall 30 is constructed of a suitable substrate material such as a high heat transfer material as may be found in the text, "Techniques and Reactor Engineering", Glasstone, Chapter 10, Van Norstrand, Princeton 1955, on fission reactor engineering wherein this material has both excellent heat transfer characteristics and very low cross section for neutron absorption, most likely group IV or V metals (periodic table of the elements) such as zirconium or vanadium. A layer of the FLM material 14 (such as in the range of 0.1-0.5 times the thickness of electrode 40) is firmly bonded to inside wall of this canister material where there is a graded metallurgical bond formed by explosive bonding fabrication techniques as can be performed by Explosive Fabricators Inc. of Louisville, Colorado. In the simple canister of Figure 1, any FLM can be used.

In the simple embodiment of Figure 1, the cathode 40' is held between terminals 50-60 at a suitable tension such that at temperatures approaching 1500°C cathode 40' remains straight and does not buckle. Cathode 40' engages the insulated caps 20 at regions 42a and 42b which is a conventional high pressure, high temperature ceramic-to-metal seal 42. The caps 20 are preferably made from a

suitable electrically insulating hermetic material such as vacuum grade, machinable high-temperature ceramic.

The configuration of Figure 1 provides a coaxial electric field arrangement between the center cathode and the surrounding anode so that the circumference of cathode 40' is fully subjected to the FE gas and the glow discharge effect as will be more fully discussed.

It is to be expressly understood that the aforesaid dimensions of the present invention are suitable for laboratory testing, but that the invention is not limited to the particular physical sizes mentioned. Furthermore, different height to diameter ratios of the canister 10 of Figure 1 could be configured for the precise application required without departing from the present teachings. The canister of Figure 1 provides a tool for conducting research into the processes of cold fusion for different FLMS and FEs.

2. Control System

In Figure 2, a control system 200 of the present invention is set forth to provide an operating system for operating and controlling the cold fusion reactor occurring in the canister of the present invention. The gas canister 10 of the present invention is shown in Figure 2 interconnected with the system 200 of the present invention. Figure 2 sets forth use of a computer 210 as an overall control. An input/output channel is shown over lines a-r. It is to be expressly understood that computer 210 may be one or several separate computers and that one or more of the control functions a-r may be performed manually under certain design or test conditions. The following describes the operation one mode of cleaning the system.

a. Pumping to a High Vacuum

Computer 210 provides the overall operational control of the present invention. The computer over line "a" activates a vacuum pump station 212 which is interconnected over plumbing 214 to the outlet port 90 of canister 10. The vacuum pump station is activated to pump chamber 12 of canister 10 to a high vacuum such as in the range of 10^{-8} to 10^{-10} torr by means of first using any of a number of mechanical roughing pumps such as those provided by Alcatel to pump to 10^{-2} to 10^{-3} Torr and

then pumping to high vacuum with either cryogenic pumps such as provided by CTI Cryogenics or high speed turbine pumps such as provided by Balzers Inc.

b. Cleaning Reactor Surfaces

After canister 10 is pumped to a high vacuum, the computer 210 over line "b" causes a low voltage constant current power supply 218 to provide power to terminals 50 and 60 to heat the palladium wire 40 to a temperature of 800°C to 1000°C (red to white hot) for a predetermined time interval in the range such as 5 to 10 minutes. Heating of the palladium metal under the vacuum into this temperature range for such a period of time cleans the metal surface of adsorbed surface atoms by thermal desorption (typically such atoms comprise hydrocarbon and adsorbed water). Vacuum pump station 212 removes such gaseous impurities. As will be mentioned in the discussion associated with Figure 3, an optical pyrometer 352 may be utilized to provide feedback control to carefully monitor and to set bake out temperatures for electrode 40 during the cleaning process under control of computer 210.

c. Heating Canister

The interior wall 14 of the canister is now heated by the computer 210 over controls "c" which activates a conventional heater 250 to 350°C in order to boil off adsorbed gases such as water vapor, oxygen and polluting hydrocarbons from the interior 12. Heating is maintained for a suitable time interval such as 30 minutes to 2 hours or as long as is necessary to reach a predetermined desired temperature throughout while under vacuum. The heater may be, for example, a conventionally available system of two refractory heating units such as PN-11-463-105B Fisher Scientific Catalog #88 which would surround the outer periphery of canister 10 (as represented by dotted lines 232). Other approaches to heating the canister may also be used under the teachings of the present invention.

d. Purging of Canister 10

Computer 210 over line "d" then activates valve 240 to backfill canister 10 with a noble gas from containment vessel 242, the preferred embodiment employing argon or neon. Canister 10 is backfilled to a pressure of 1-20 millitorr. Recirculating pump 315 is activated thereby circulating the delivered noble gas through processor 271 which removes impurities transported therethrough. Processor 271 may be a

conventional gas centrifuge which delivers impurities out over line 272 for collection and/or analysis. As will be discussed later, analysis of the impurities is important in understanding the cold fusion processes. Processor 271 is under control of computer 210 over lines "h" and it also provides data back to computer 210.

5 The high voltage power supply 220 is run by computer 220 over "e" for a number of minutes at current in the range of 1 ma/cm² to 50 ma/cm² of surface area of the palladium wire 40. The high voltage current regulated output supply is capable of operating up to 1,000 volts. The one-minute run provides enough operating time to sputter off 50-500 Angstroms of the FLM surface of the cathode to remove any
10 remaining adatoms from the lattice of the FLM not removed earlier.

Polarities of the high voltage power supply 220 can be reversed by computer 210 over leads "e" to sputter clean the surfaces 14 of the anode structure 10. During a polarity reversal, the "ANODE" acts as a cathode. This process can be alternately repeated as many times as necessary to insure the removal of all impurities from the
15 lattice.

In addition, while sputtering of the cathode 40' is occurring, the computer 210 can activate the low voltage supply 218, controlling lead "r" to generate a magnetic field B around the cathode 40' to increase sputtering via increased ionization efficiencies as will be discussed later.

20 Chamber 12 is then filled with deuterium, $_2\text{H}^2$ isotope, from gas administration system 252 at 10 millitorr to 10 mm (of Hg) by activating valve 250. It should be expressly understood that FE gas administration system 252 is able to provide any one of the three hydrogen isotopes (common hydrogen, deuterium, tritium) or any desired mixture and ratio of the three isotopes. The mixture ratio and administrative flow is
25 controlled by computer 210 over line 211. This capability is important in laboratory situations for investigating the cold fusion processes and for tuning the mixture.

Deuterium gas is delivered from tank 252 through a filter 253 for insuring delivery of a pure hydrogen isotope (e.g., deuterium) or mixture. Filter 253 may be, for example, a standard palladium heated membrane for providing high purity
30 hydrogen (e.g., 99.999% to 99.9999% purity). Computer 210 activates valve 250 over lines "f" to fill the system.

The power supply 220 is then turned on by computer 210 in a normal polarity constant current mode (i.e., minus at terminal 50) for the length of time required to reach a solubility of 0.74 atoms of hydrogen per atom of FLM when the FLM is the preferred embodiment metal, pure palladium. the level of solubility of deuterium can be measured as a function of resistance and temperature of the FLM as seen in Figure 4. See the section entitled "Resistance Measurement" for a discussion of Figure 4. Such solubility in atom FE per atom Pd units may be expressed below:

$$\text{FE}^{\text{atom}}/\text{Pd atom} = 0.74$$

Formula 2

Solubility may vary for other FE's in FLMs, but similar curves also exist for such metals showing a peak 400 of desired solubility.

In a following step, polarity of the electrodes may be reversed under the hydrogen pressure and the current adjusted to a level that keeps the Pd cathode 40' (Figure 2) at 900°C. These conditions are maintained until the R/R₀ ratio returns to 1.0 at point 405 as seen on the graph in Figure 4. At point 405, the FLM is totally depleted of hydrogen. The same conditions are maintained for 10 minutes at a variation tolerance of 0.1% for R/R₀ to insure that the total depletion of solubilized hydrogen from FLM cathode 40' has been achieved.

At this point, the chamber and each of the electrodes have been scrubbed of impurities and the system is ready for operation. It is to be expressly understood that the ranges of operation for time, pressures, current densities and the like are those for the geometry of the preferred embodiment using cast annealed palladium as the FLM. It is to be understood that different ranges could be used under the teachings of the present invention for other geometries, for other FLMs and for various test experiments. Operation of any reactor configuration will necessarily have to be empirically tested in a simple canister mode as exhibited in Figure 1 before design implementation. Furthermore, it is to be expressly understood that the order of operation set forth above may be varied, or some of the steps may be eliminated and still fall within the teachings of the present invention. Whatever the method(s), the intent of this section of operation is to have the reactor electrodes or vessel absolutely free of any trace of impurities.

3. Operation of Fusion Metal Lattice Cathode

40 in Energy Production Mode

The operational system of the present invention is shown in Figure 3 which is used in conjunction with the equipment of Figure 2 and will now be discussed.

a. Delivery of FE Gas

After cleaning, it is best to keep valve 250 (Figure 2) open by computer 210 to add gas to the recirculation loop 322. The desired mixture ratios of hydrogen gases (1, 2 or 3) are maintained by monitoring - the output of mass spectrometer 351 over lines "o" and the rebalancing program of computer 210 calling for any necessary gas makeup from FE vessel 252. At this point all other inlet and outlet valving is shut off except for those valving, balancing and monitoring systems tied to loop 322 as just discussed.

For example, a mixture that could be delivered into the chamber 12 from supply 252 (by means of control 211 from tanks 1, 2 or 3) may be:

tank 1 = 99% of deuterium

tank 2 = 0.9% of tritium

tank 3 = 0.1% of hydrogen

Such a mixture may be delivered into the system while output "o" of the mass spectrometer determines the percentages. If the mixture is incorrect, computer 210 adjusts the delivery system over lines 211 to fine tune the gas composition.

The pressure of FE gas in the loop 322 and chamber 12 should be considered to be critical to all other parameters of operation and, therefore must be maintained at a specific set pressure. Pressure should be set to just enough pressure of the FE gas which is necessary to initiate and maintain a desired level of measurable reactor activity. This pressure is set by the regulator 251 at the inlet from the FE gas source 252 as required by the computer 210 and over line "p".

By keeping FE pressures low but in a range where a desired electron emission current density may be achieved in polarity reversal for FE release from the FLM, the greatest safety margin is assured. In this condition, any space charge reversal over the FLM or glow discharge current reversal caused by changing the polarity on terminals 50 and 70 can most quickly release hydrogen from the FLM cathode 40'.

FE pressure when using palladium electrodes in a preferred embodiment diode discharge mode may best be set between 10mTorr and 10mm (of Hg) pressure. In this preferred embodiment voltage potential between cathode 40' and anode 14 is run at about 200 volts at a current of 1.2 ma/cm² of Pd surface. Voltage values will likely vary with electrode geometry and spacing distances. Curves for predicting voltage values shown in Figure 9 for H₂:

$$V_{op} = f(k, 1/p, 1/d) \quad \text{Formula 3}$$

where V_{op} = voltage of operation

K = constant

p = pressure

d = distance between anode and cathode

Pressure is adjusted to obtain this voltage. (Figure 11 illustrates this modality).

It is to be understood that each particular design of cathode-anode system geometries, the operating pressures, current voltages, FLM resistances, operating temperatures all need to be determined empirically until the desired design parameters of each experimental reaction are ascertained. Once obtained, the computer is programmed to control the system as shown in Figure 1-3 of the present invention. Highest safety is achieved by operating FLM materials about 50° - 200°C below thermionic emission temperature.

b. Recirculation of Gases

As seen in Figure 3, Pump 315 is capable of circulating the delivered FE gas through the system such that the gas (volume per unit time) is continually flushed through the system (i.e., loop 322 and chamber 12). Pump 315 is under control of signals "g" as generated by computer 210. Pump 315 pumps FE gas through heat exchangers 310 and 320 that can be run in either of two possible modes - either for heat addition or subtraction over ports 312. Typically since gases exiting the system through exit port 80 (after a fusion or other nuclear reaction experiment) may be at very high temperatures, heat exchangers 310 and 320 will be used to remove heat from the system.

A first, power generation embodiment comprises pure thermal transfer wherein heat is carried away by convection or forced gas movement over the wire

surface as provided by the recirculation loop 322 in conjunction with pump 315 as seen in Figure 3. It shall be understood that pump 315 can be turbines or fans designed for high temperature operation with blade materials such as one finds in Concorde or SR-71 aircraft engines.

5 A second power generation embodiment employs a mode of heat transfer in this wire/surface FLM system by photonic radiation in the far infrared to high UV spectral range. To keep thin FLMs from reaching ranges near melting (in the embodiment using palladium, melting temperature is 1542° C) heat absorbers are disposed in the power generating system.

10 In a simple canister system, photon radiation is absorbed in canister surface 14 with thermal transfer to canister 10 which in turn thermally transfers heat into the exchange loop 335 servicing blankets 380. Canister 10 serves as the second heat absorber. It is also to be expressly understood that the heat by-product can be collected by heat exchanger 320 for purposes of performing work and will therefore
15 be connected to and operative with heat exchange 345 via pipes 312b, as discussed later. Any heat exchanger discussed herein, if it removes heat at a high enough temperature to produce steam, will transfer heat energy to exchange 345.

Referring briefly to Figure 6, there are two preferred power generation embodiments in the mode where a three electrode system comprising cathode, anode,
20 and idler 601, 602, 603 FLMs have no cooling ports 610. In such embodiments, FLMS 601, 602 and 603 are of a very thin structure (.001-.500) where they are able to radiate their heat load in two modes. (See section 6 "Multiple Electrode Systems; Three or More" for further detail.)

c. Testing for Obtained Fusion or Other Solid State Nuclear Reaction

25 High power supply 220 is activated by computer 210 over lines "e" to apply power to terminals 50 and 70 after delivery and circulation of the FE gas into canister 10. Supply 220 is programmed to ramp up (i.e., linear ramp, etc.) to the voltage necessary to obtain glow discharge. This voltage is the voltage necessary to overcome the ionization or breakdown voltage and such voltages are known in the literature for
30 different gases and gas pressures. Glow discharge will be more thoroughly discussed

As hydrogen is absorbed, cathode 40' exhibits a change of resistance over time as shown in Figure 4. Cathode 40' (for palladium) will commence following the curve of R/R_0 through points 405, 400, 410 and 420 and until 430, a postulated point at which a nuclear reaction may occur. The system of the present invention monitors this movement until any ignition and through the postulated nuclear reaction. This monitoring process will be discussed later and provides important feedback information and control to the computer.

To summarize, power from high voltage supply 220 is ramped on to apply power to terminals 50 and 60, as shown in Figure 2 to be controlled by computer 210 (+ to terminal 50), and to provide the appropriate current per square centimeter of surface area of the cathode 40' which is in the range one milliamp per centimeter to one amp per square centimeter range. The condition of glow discharge is entered and maintained as a predecessor to any nuclear reaction.

One approach to monitor resistance of cathode 40' (and therefore to monitor between points 405 to 430 on Figure 4) is to watch the voltage between terminals 50 and 60 across the wire 40 when a small constant current from supply 218 is run through the FLM. Such a current is realized by passing a constant current between terminals 50 and 60. By virtue of measuring the voltage through voltage monitor 305 and the temperature of wire 40 through optical pyrometer 352 which monitors the infrared heat output from the cathode surface via window 393 inside of canister 10 it is possible to determine the resistance of the wire of cathode 40'. Optical pyrometer 352 and the voltage monitor 305 are interconnected with computer 220 over lines i and j respectively to receive control signals and to provide data to the computer 210.

Note that wire cathode 40' may be precalibrated as described in the prior section with no saturation of hydrogen in the metal (i.e., point 405 in Figure 4). Also, wire cathode 40' may be run up and down the temperature range such that the resistance of the wire 40 or cathode form and how much hydrogen is in the wire can be determined from the information in Figure 4 as will be explained hereafter.

As wire FLM cathode 40' reaches critical implantation of FEs which be in the critical range of 0.5 to greater than stoichiometric quantities of fusion elements per

atom of FLM, somewhere in that range a nuclear reaction is postulated to initiate. In the case of palladium this is anticipated to be

$$\text{FE}^{\text{atoms}}/\text{Pd}^{\text{atoms}} = 0.5 \text{ to } 1.1 \quad \text{Formula 4}$$

At this point one may see an increase in temperature which, if the cathode is palladium that is saturated with hydrogen, will likely change resistance abruptly at point 430 due to fusion induced temperature rise. The temperature rise in the lattice may be due to reactions such as deuterium-deuterium fusion that produces a 3.02 MeV proton that transfers its energy to the FLM lattice, a reaction for which the invention is particularly well suited to test.

d. Detecting Gamma Radiation and Neutrons

Upon any fusion or other solid state nuclear reaction, radiation event counts will be seen in specific energy bands detected by the gamma ray spectrometer 354 via gamma radiation window 391 inside of canister 10. The spectra obtained by these gamma ray photons is indicative of specific nuclear reactions taking place. For instance, a reaction of neutron plus proton results in deuterium and energy release gained therefrom should be exactly at 2.23 Mev. Any fusion reactions (e.g., deuterium on deuterium, deuterium on tritium, deuterium on helium 3, tritium on tritium, i.e., any of the FEs fused in combination with one another) have smaller probabilities of reactivity than a thermal neutron on a proton, but since the mechanism is not yet known, there is a possibility that any light fusion element reactions, including fission generating reactions, known thus far may happen. If so, such reactions may be identifiable by gamma ray spectrometer 354 because the emitted gamma ray helps identify only one specific nuclear reactions.

The use of spectrometer 354 allows one to monitor occurrence of photon reactions. Spectrometer 354, used in conjunction with neutron spectrometer 353 which receives incident neutron radiation through window 392, provides definitive measurement for neutron producing nuclear reactions that occur within cathode lattice 40'. It is to be expressly understood that all radiation measurement windows should be "invisible" (low absorption coefficient to radiation being measured) while maintaining the necessary thermal and pressure constraints required by design of reactor canister 10. Gamma ray spectrometer 354 and the neutron spectrometer 353

are commercially available and are controlled and transmit data over lines k and l respectively with control computer 210.

The present invention provides, in the test fixture of Figure 1, a valuable research tool in understanding the nature of processes related to cold fusion or other nuclear reactions, especially for testing different metals and alloys and which may be used efficiently and quickly to discover which FLM materials and alloys should be used to obtain the highest energy release.

It is to be expressly understood that onset of any nuclear reaction can be detected under the teachings of the present invention by monitoring resistance of the FLM cathode 40', temperature of the FLM 40 by optical pyrometer 352 and generation of gamma rays and/or neutrons thereof. Design parameters associated with particular pressures of HE gas, geometries of the FLM electrodes, percent of each isotope in the HE gas, spacings of FLM electrodes, temperatures and volumes for any individual configuration are best estimated by calculation but can be empirically determined in a test fixture of the style of Figure 1 before being used in a power generation reactor. The methods and apparatus of the present invention provide an efficient universal design tool for such empirical analysis.

e. Obtaining Thermal Energy for Work

Surrounding canister 10 but disposed outside detector windows 391, 392, 393 is a neutron absorption blanket combined with a gamma absorption blanket jointly referred to as 380 as seen in Figure 3. Such gamma absorption and neutron absorption blankets are designed by techniques well known and in standard textbooks of nuclear fission reactor engineering to produce thermal energy by absorption of the energetic gamma rays and neutrons that are produced from the metal lattice 40. This absorber blanket, for example, is shown in "Glasstone-Techniques of Reactor Engineering", Chapter 10, Van Nostrand, Princeton, 1955, incorporated herein by reference.

Any heat created by absorption of the gamma radiations and neutrons by the blankets 380 is removed from the system by pump 330 under computer control "m." A suitable coolant is circulated through the blankets and is chosen to have a very low capture cross-section for neutrons flowing in the cooling return loop 335 such that the coolant itself does not become radioactive. Coolant is circulated in loop 335 by pump

330 and circulated throughout the interior of the neutron and gamma absorption jacketing (as shown by the dotted line) 380. Line 335 is a high pressure line with high pressure seals. Note that it is necessary to keep the coolant in a fluid state and to take all possible precautions to keep boiling coolant bubbles from forming. Coolant flows through heat exchanger 340 and according to heat exchange technology that is standard to nuclear fusion reactor technology this would transfer its heat to water circulation line 345 that is run out to run conventional steam turbines for the process of electrical or mechanical energy power generation. Techniques to do this are also well known and are found in standard texts and designs for nuclear fission reactors.

Heat from heat exchanges 310 and 320 is combined with the output over 345 to provide output power from the system.

f. Fusion By-Products

If fusion or another nuclear reaction is obtained, the present invention provides a method and mechanism for sampling nuclear reaction by-products. It may be desirable in certain fusion reactions to periodically shut off the supply of high power ionization current from power supply 220. Supply 220 is shut off for a small period of time such as 5 to 20 seconds to leak a very small amount of gas out of cathode 40'. If there are specific fusion products building up in the lattice, this gas leakage would be represented especially by build-ups of helium, helium 3, helium 4, and tritium as detected in processor 271. It is important to measure these levels periodically for safety and to thereby understand the nuclear processes taking place. These light fusion elements include: hydrogen, deuterium, tritium, helium 3, helium 4.

Mass spectrometer 351 checks on levels of fusion by-products that are being created in metal lattices 40.

Liquid scintillation counter 350 should be given special attention as it may be critical to monitoring tritium production. Liquid scintillation is the technique with the greatest sensitivity to changes in tritium levels by measurement of emitted beta rays. A small sample of the pumping return loop 322 would be bubbled through the liquid scintillating cocktail. In the cocktail of standard liquid scintillation counters there is a scintillation material that is activated which gives off photons in relation to the

amount of energy of the beta decay of tritium. The counter also helps distinguish ^3H as opposed to ^3He which the mass spectrometer cannot do alone.

All of the detectors are tied to computer 210 for transfer of control and data for precise operation of the present invention and for precise feedback control.

5 The present invention, therefore, provides a system for periodically monitoring by-products of the fusion reaction for safety and research purposes. This is accomplished by programming computer 210 to shut down power from supply 220 for a predetermined period of time thereby allowing gaseous by-products to be delivered into chamber 12 from the FLM cathode 40, these by-products are then
10 delivered to suitable detectors such as mass spectrometer 351 and scintillation counter 350 for analysis.

g. Gaseous Fusion Elements

The major portion of the gases admitted to reactor vessel 10 in an operating mode will likely be isotopes of hydrogen such as hydrogen, deuterium and tritium. It
15 is not, as yet ascertained, exactly what nuclear reactions are going on in cold fusion as broadly defined. Hence, use of lighter elements such as lithium isotopes, lithium 5, lithium 6, lithium 7 are possible. Major components of the FEs in a preferred embodiment power generating mode may likely be more than 99% deuterium.

If lithium is desired in the gas phase of this reaction, it has a measurable vapor
20 pressure at temperatures of operation on the order of 800°C for the gas canister 10. The boiling point of lithium is 1347°C . The melting point is 180.54°C . If it should be desired to operate this reaction at lower temperatures than that necessary to keep the lithium in vapor phase, lithium may be drifted into the fusion lattice metal elements in gas diffusion ovens prior to use as is well-known in the semi-conductor
25 art. Such ovens are used in the semiconductor industry.

The rods, tubes assemblies of the FLMs could also be displaced into Chamber 10 along with a source of elemental lithium. The tube lithium could be evaporated at temperatures up to 1000°C into the gas in the canister. Plasma bombardment would then implant lithium into the lattice of the cathode electrode.

h. Controlling Fusion

Any resulting fusion reactions are monitored by radiation output monitors 352, 353, and 354. An appropriate program in computer 210 assembles data as monitored and acts under proper feedback control time constants to adjust all reactivity rate parameters, especially current and polarity of glow discharge as provided by supply 220. Such programs are either available in the art or can be written and implemented by one of ordinary programming skill without excess experimentation. When temperatures rise, FLM cathodes (e.g. cathode 40') can become thermionic emitters in the range 600 - 1500°C. In Figure 11, in thermionic emission mode, electrons are boiled off a metal surface. These electrons, in the charge balance reaction shown in Formula 8, provided hereafter, can combine with the surface FE lattice gas 1024 (as shown with arrows) to form the combination of FE^+ shown in Figure 11 as a deuterium ion 1100 with an electron 1110 that then escapes with a thermal velocity away from the surface 1140 as determined by gas pressures, temperatures and pressure gradients immediately over the FLM material surface.

In Figure 11, points 1105 show that there is a likelihood of finding FE gas molecules 1024 of Figure 11 further from the surface immediately over the FLM atoms 16 of Figure 11.

4. Multiple Electrode Systems: 3 or More

Referring to Figure 6, a multiple electrode system of the style which may be more suited to power generation than the simple coaxial reactor of Figure 1 is shown. In Figure 6 there are three substrate tubes 620. Typically a metal such as copper or other metal that has low mobility for hydrogen is used. It is metallurgically bonded to FLM thickness 630. In Figure 6, each elongated tube 620 has an inner pipe space 610 (extending the full length) that allows passage of coolant through the FLM electrodes. The reported nuclear reactions by Pons and Jones seem to generate much heat in the electrodes without much energy emitted in the form of neutrons. The coolant passages of Figure 6 provide a means of removing such heat. Hence, a fair portion of the energy is removed from the metal lattices by virtue of a coolant flowing through the hollow cores 610 of tubes 620.

Tube 620 is metallurgically bonded to FLM material 630. The substrate metal 620 is bonded to the fusion lattice metal 630 with a system of bonding that does not leak hydrogen from the FLM through the bond. This is important in order that lattice pressures of FE fusion element gases may be maintained in fusion lattice metal 630.

5 This seal may be achieved by a graded alloy between substrate metal 620 and fusion lattice metal 630 and performed by techniques presented in standard metallurgy texts.

In the three or more electrode system of the present invention and at any point in the energy generating cycle, one electrode (for instance in Figure 6, 601) may be used as a cathode. In this circumstance, electrode 602 may be used as an anode and electrode 603 is an idler. In this system, cathode 601 is connected to the negative of the glow discharge power supply 220. The electrode 602 is connected to power supply 220 to run as the anode. With the incoming electrons to anode 602, anode 602 which may have previously been running as a cathode is at first depleted of hydrogen, deuterium, lithium, tritium, helium, or, in other words, all of the isotopes that may have been built up such that depleting elements especially ^3He and ^3H may be harvested and retrieved as valuable reaction by-products. Specific FLM materials which are permeable both to hydrogen and helium are desired.

10 In a commonly preferred embodiment, cast palladium FLM does easily diffuse hydrogen, deuterium and tritium. Mobilities and solubilities for helium may be found in the literature on solubilities of helium in palladium.

20 Since the system operates with recirculation pumps of the gases involved, these fusion by-products are pumped out of the system through collection port, such as port 272, when harvested by a processor 271, a gas centrifuge for gas separations of these elements. Electrode 603 is idle in the configuration where electrode 601 is responsible for generating the power and electrode 602 is the anode. Electrode 603, when inactive, is known as the idler. Previous to this time, the idler would have been the anode and while an anode would have already discharged its load of fusion reaction by-products. In operation, each idler is biased electrically somewhere near the potential of the cathode, but just short of that potential necessary to drive it into necessary fusion gas saturation which may produce fusion or other nuclear reactions.

In this manner, every time the cathode starts to build up excesses of fusion by-products, the system can be switched such that the electrode which has been the cathode becomes the anode to dump its load of by-products. The electrode which had been the anode becomes the idler and begins to recharge with hydrogen to be ready for a next electrolytic production cycle. The electrode which had been the idler has theoretically been raised to the borderline of necessary saturation pressures to an active electrode becomes the cathode. The newly selected cathode is pumped up with current and starts being the reactive electrode nearly immediately. The uniqueness of this system is that there can be a large number of these cells and they can be small and compact. All such cells are under separate control such that if any one cell is operating ineffectively, arcing or approaching limits unacceptable to reaction control, the out-of-tolerance activity would not require deactivating a whole reactor, but only one cell at any given moment. The above described operation is summarized in the following chart:

TABLE II

	Time 1	Time 2	Time 3	Time 4
<u>Electrodes</u>				
601	Cathode	Anode Idler	Cathode	
602	Anode Idler	Cathode	Anode	
603	Idler	Cathode	Anode Idler	

Computer 210 is suitably programmed to operate the three electrode system of Table II.

Rotation of use among the electrodes provides the advantages as previously discussed. It is to be expressly understood that more electrodes could be utilized under the above teachings than the three shown and operate in same sort of round-

robin mode. Also, any number of independent cells of numbers of electrodes greater than three could be combined to form a reactor.

If there are fusion by-products which do not diffuse through the lattice and keep building up in FLM elements, the electrodes can be replaced on an appropriate maintenance schedule.

5. Resistance Measurement

In the preferred embodiment where the FLM is wire 40 with contacts 50 and 60 of Figure 1, the current source power supply 218 is set to a steady regulated constant current such as 1.00 ma. By reading the voltage as measured by voltage monitor 305, one can then obtain the resistance of the FLM wire by:

$$\begin{aligned} R &= E/I \\ &= E/0.001 \text{ amp} \\ &= 1000 E \end{aligned} \quad \text{Formula 5}$$

where E is determined by voltage monitor

The FLM cathode 40', as mentioned, is precalibrated by being run as an anode until the wire hits a non-varying reading of resistance at point 405 in graph of Figure 4. This point is R_0 , the point at which the FLM wire is totally depleted of hydrogen or its isotopes.

To accurately measure readings of resistance, it is necessary to subtract from the above formula any currents that are due to electron emission from cathode 40'. One appropriate electrical technique to do this is to divide the gas discharge emission current in half and feed the equal halves of that current from supply 220 to the FLM cathode 40' via the two terminals 50 and 60. The two currents nullify and do not show up as a voltage difference on voltage monitor 305.

Supply 218 is then set at a nominal value of 1.0 ma and connected to the wire circuit through terminal 50-60 and the computer reads the voltage. If one knows this resistance with total hydrogen depletion, one then may calculate the level of total FE gas solubility. The FLM is carefully calibrated by saturating with FE gases out to the point of postulated fusion ignition 430 in Figure 4. If no structural deformations happen to the FLM cathode 40', this calibration graph may be used to determine the

saturation levels in cells in a power generating reactor. The first part of the graph shown in Figure 4 is an extremely reproducible curve for hydrogen in palladium with the ratio of saturation resistances to hydrogen depleted resistances, R_o , as related to time. This graph is a reproduction of the graph presented in "Electron Phonon Coupling and Superconductivity" as presented by J.P. Burger in the book Metal Hydrides, Gust Bambakide Ed. Plenum Press, 1981, incorporated by reference. The discontinuity 430 has been added to this related art graph to represent the postulated event of fusion or other nuclear reaction. The literature on this resistance measurement is extensive due to concerns of material studies on fission reactor safety where researchers were looking at solubility characteristics of fission reactor metals to hydrogen deuterium and tritium.

6. Mechanism of Operation

It is anticipated to achieve fission or other nuclear reactions, lattice pressures of FEs as the FLM approaches stoichiometric solubilities (i.e., atom FE/1ATOM Pd) becomes extreme. To quote Pons and Fleischmann and Hawkins in their Preliminary Note, Electrochemically Induced Nuclear Fusion of Deuterium, J. Electroanal. Chem., 261 (1989) 301-308. "Our own experiments with palladium diffusion tubes indicate that values as high as 0.8 ev can be achieved readily (values as high as 2 ev may be achievable. The astronomical magnitude of this value can be appreciated readily: attempts to attain this level of D^2 [step IV, $P_{ads} \rightarrow P_{ads} - D_2$] would require pressures in excess of 10^{26} atm."

From this, it can be seen that the present invention would be capable by virtue of maintaining significantly higher pressures of FEs at the surface of the cathode 40' in the pressure range of D+ 100ev - 5000ev of obtaining lattice pressures of FEs in excess 5×10^{28} atm. A usual glow discharge cathode drop value of 400 volts results in:

Present invention = 400 ev

Pons = .8 ev.

$$\frac{400 \text{ ev}}{.8 \text{ ev}} \times 10^{26} \text{ atm} = 5 \times 10^{28} \text{ atm.}$$

Formula 6

It is anticipated that such pressures are so extreme due to the vibrational modes of the hydrogen in lattice sites which normally only allow for occupancy by only one FE atom, these sites may be populated for small lengths of residence time by multiple atoms or ions of FEs. Such multiple occupancy can be envisioned as "cluster atoms" as recognized in the following: "Hydrogen Induced Lattice Expansion and Effective H-H Interaction in Single Phase PdH_x", R. Feenstra, R. Griessen and D.G. de Groot, J. Phys. F: Met. Phys. 16 (1986) 1933-1952 and "Nuclear Magnetic Resonance of Hydrogen Absorbed into Palladium Wires", R.E. Norberg, Physical Review, 86, 745-752 (1952). The teachings of these references are herein incorporated by reference. Closer resonant excited FE-FE interactions in combination with muons or electrons are postulated by others to be capable of tunneling the coulomb barrier and fusing. The Norberg reference above teaches a technique of solubility monitoring by NMR rather than resistance. This invention provides a unique and complete system for testing this hypothesis.

7. Utilization of the Glow Discharge Plasma

Plasma is an ionized state of matter in which charge balance tends to be maintained. That is, in an electric glow plasma, the number of free electrons per unit volume will very nearly balance the magnitude of ion charge per unit volume. To understand the unique mode of operation of the present invention, reference to the following might be most helpful in providing insight to the function and utilization of glow discharge as a driving pump to absorb FE gases by low energy implantation into the FLMS to produce a cold fusion or other nuclear reaction as tested by the present invention.

It is to be expressly understood that it is nearly impossible to describe motions of all ions and electrons in a mere cubic centimeter of plasma for one second even through the use of the best hydrodynamic code supercomputers. Although the hydrodynamic events occurring in glow discharge are complex, the basic effects that are pertinent to the present invention, as presented in the following texts on glow discharge plasma, support the basic postulates presented herein and, these are specifically incorporated herein by reference:

- a. Electrical Discharges in Gases -
F.M. Penning
The Macmillan Company, New York
Phillips Technical Library - 1957
see especially pp. 12-13, 41-48
- b. Conduction of Electricity in Gases -
J. Slepian - PhD., Educational Dept.
Westinghouse Electric & Mfg. Co.
East Pittsburgh, PA - April 1933
see especially pp. 136-137
- c. Gaseous Conductors: Theory and Engineering
Applications, James Dillon Cobine
Dover Publications, Inc., New York - 1958
see especially pp. 205-233
- d. Electric Plasmas, Their Nature & Uses
A. von Engel
International Publications Service
Taylor & Francis Inc.
New York 1983
see especially pp. 131-139
- e. Thin Film Processes
Ed John L. Vossen
Werner Keen, Academic Press
1978 - New York, San Francisco, London
see especially pp. 24-31
- f. Deposition Technologies for Films and Coatings: Developments and
Applications
Rointan F. Bunshah et al.
Noues Publications 1982

Figure 5a comprises circular lines 530, which represent magnetic field lines B generated by running current I into the page as supplied by low voltage power supply 218 at a constant DC current. This creates an electron confinement that vastly increases ionization efficiencies of each electron emitted from surface of FLM cathode. This magnetron effect is better understood by searching "magnetron" in the indices of the above references a and f. This is important since when used in conjunction with the cleaning and implantation modes of the FLM cathodes of the present apparati Figure 1 and Figure 6, as such increases ionization efficiencies. In

Figure 5b, the flux J represents the current density per square centimeter of FLM cathode 40' surface.

Figure 7a (which corresponds to Figure 2.9 of Reference f above) presents the basic distribution of cathode fall potentials in the cathode region of a glow discharge. Also included is ion and electron densities in the normal glow discharge mode. Most of the electric field potential drop appears in the region of the cathode surface. Cathode voltage potential drop is shown as V_c in Figure 7a. A typical operation curve of cathode drop potentials for operation in hydrogen in Figure 9. The curve of Figure 9 is obtained for geometries in the related art reference. The electric field potential which is maintained by glow discharge conditions accelerates FE ions into the FLM lattice within an energy range of 0 ev - 5000 ev. Potential, V_c , seen in Figure 7a, is called the cathode fall potential. The present invention provides an apparatus and method which utilizes potential V_c as an acceleration activation device for the purposes of driving the FE positively charged ions into the FLM surface. More specifically, the present invention uses potential V_c in either a Normal Glow Discharge mode or an Abnormal Glow Discharge mode for the purposes of accelerating the FE ion into the metal lattice. Lattice pressures obtainable with the method and apparatus of the present invention are in the range of 2-1000 times more than the aqueous electrochemical reactions of Pons, Fleischman, Jones, or any other FLM system wherein the FLM is surrounded by aqueous ionic solutions of FEs.

In Figure 8 (which is a modification of Figure 11 in "Surfaces and Disorder" by J.W. Halley, Trans Tech Publications (1985) herein incorporated by reference), an FE ion of hydrogen isotope 800 is shown dropping through the cathode fall potential V_c . In Figure 8, the rectangular shapes are the FLM atoms and the circular mappings represent the typical occupancy at stoichiometric solubility levels of FEs. The ion 800 becomes implanted at an occupancy location in the FLM under the teachings of the present invention at a location 810 within the lattice such as at site indicated by arrow 812. At a standard cathode fall potential in 1 mm of Hg (FE) for H_2 , the potential V_c value is approximately 250 volts, as seen in Figure 9.

The flow discharge of FE gas charging method for hydrogen is taught in "Nuclear Magnetic Residence of Hydrogen Absorbed into Palladium Wires" by R.E.

Norberg, Physical Review 86, 745-752, 1952. At 0.5 mm of H₂ (FE) pressure, the potential is about 450 volts. Figure 9, which is taken from page 229 of Cobine, shows this relation for H₂. In general, FE ion 800 arrives with the energy (in ev) of the full scalar value of potential V_c. The ion energy formula is in Penning, page 12. This can be approximated as:

$$E_{\text{absorption}} = + (\text{Scaler Value of } V_c) \times 1 \text{ ev}$$

Formula 7

In a constant current mode of operation, of power supply 220, the cathode potential V_c will tend to fall off with increasing pressures of FEs, but, as is known in the discharge art, it is possible to maintain glow discharge conditions to at least 13 ATM. Potential V_c is typical and varies inversely to gas pressures of operation, but any gas discharge potential obtained in the present device will be in excess of 800 millivolt potential mentioned in the experiment of Pons and Fleischman.

The present invention makes available the cathode fall potential as a mechanism for accelerating FEs into a metal lattice within any pressure range within which glow discharges in hydrogen isotope FE gases may be maintained to produce cold fusion. The present invention is also operable in the abnormal "glow discharge" mode (see Cobine, pg. 207). As mentioned, the transition into glow discharge is accompanied by a drop in voltage, (potential V_c). When the current is increased through cathode 40' beyond a critical value, the discharge voltage increases with increasing current. This is termed "abnormal glow" discharge. Additional increases will cause an arc to occur. Under program control, computer 210 of the present invention continually monitors the current with sensor 300 over "g" and maintains the current in the range below arc and above normal discharge.

Energies and velocities typically much greater than 10km/sec for hydrogen isotope FEs make the system of the present invention insensitive to surface fouling as the FEs pass directly through any remaining surface adatom layer (after scrubbing) and are implanted a typical distance of 50-300 Angstroms into the lattice, which is a distance of many atomic layers as illustrated by location 810 in Figure 8.

A sputtering process action illustrated pictorially in Figure 10 (corresponding to Figure 5.7 of Reference f) as a mechanism to clean adsorbed atoms off the surfaces.

With the use of a noble gas such as neon or argon in low percentage concentrations in the FE gas, sputtering by incident ions of noble gas 1050 causes surface disposed adsorbed atoms to be ejected from the surface. A very adequate description of the sputtering mechanism is in Bunshah on page 181 which is incorporated by reference.

5 The present invention makes significant use of the mechanism in cleaning mode specifically for removing surface atoms of FLMs in a glow discharge cold fusion reactor.

If FLMs are run at a temperature in the range of 900-1100° C or more specifically at a temperature just below the thermionic electron emission temperature level of the FLM cathodes, the reactor will quickly regulate itself with a negative coefficient of reactivity. The mechanism may be described as follows: as the temperature hits the thermionic emission level, electrons are suddenly ejected from the surface creating two effects. Referring to Figure 7 and 7b, the space charge changes its sign to negative over the cathode surface. The following reaction occurs:



At the same time the changed space charge nullifies the cathode potential drop. The amount of time for reversal of the space charge to occur is rapid as it is based on electron mobilities, which are extremely rapid in plasma. The rate limiting factor is anticipated to be the time to heat FLM surface into emission mode.

20 In the present invention, some of the following nuclear reactions are postulated to be obtainable due to the two-to-three orders of magnitude increase in lattice pressure:

- (a) ${}_1\text{H}^2 + {}_1\text{H}^2 \rightarrow {}_1\text{H}^3 + {}_1\text{H}^2$ (4.0 Mev)
- (b) ${}_1\text{H}^2 + {}_1\text{H}^2 \rightarrow {}_2\text{He}^3 + {}_0\text{n}^1$ (3.2 Mev)
- 25 (c) ${}_1\text{H}^2 + {}_1\text{H}^3 \rightarrow {}_2\text{He}^4 + {}_0\text{n}^1$ (17.6 Mev)
- (d) ${}_1\text{H}^3 + {}_1\text{H}^3 \rightarrow {}_2\text{He}^4 + 2 {}_0\text{n}^1$ (11.3 Mev)
- (e) ${}_1\text{H}^1 + {}_1\text{H}^1 \rightarrow {}_1\text{H}^2 + {}_1\text{e}^0$
- (f) ${}_1\text{H}^2 + {}_1\text{H}^1 \rightarrow {}_2\text{He}^3$
- (g) ${}_2\text{He}^3 + {}_1\text{H}^1 \rightarrow {}_2\text{He}^4 + {}_1\text{e}^0$
- 30 (h) ${}_2\text{He}^3 + {}_2\text{He}^3 \rightarrow {}_2\text{He}^4 + 2 {}_1\text{e}^0 + {}_1\text{H}^1$
 $\quad \quad \quad \rightarrow {}_2\text{He}^4 + \text{energy} + \text{energy}$

Testing the occurrence of the above described reactions can be proven by merely looking at the data out of the neutron detector and gamma ray detector. For reactions with a beta decay, the designer might want to substitute a beta spectrometer or alpha spectrometer for one of the above instruments using the appropriate exit non-absorbing windows out of reactor canister 10. Such reactions have not been obtained in the present system of Pons or the other aqueous approaches.

It is important to note that radiation energies are near absolute signatures of each separate possible fusion reaction.

It is to be expressly understood that many of the described and novel processes and structures set forth herein are separate and may be used separately in other cold fusion systems other than test systems. (e.g., energy producing, aqueous systems). Because the exact nature of cold fusion as broadly defined above is not known, the ensuing disclosure illustrates a preferred embodiment which will be subject to empirical analysis.

The versatility of the reactor comprising canister 10 when used in a test mode is made evident from the following discussion. As an example, the simple glow discharge cell of Figure 1 can be hooked up with electrically polarities reversed, as is true for any anode/cathode as described herein. In the reactor of Figure 1, reversal of polarity makes electrode 40 the anode and surface 14 as the cathode surface. Please note that electrode 40 may be a solid wire, a large diameter rod or a tube (as seen in Figure 13). In each configuration, electrode 40 must be made of electrically conductive material.

When used as a cathode, electrode 40 is coated with any of the FLM metals earlier described. Where it is more convenient, o-ring seals can be used to replace ceramic-to-metal seals 42. However, care must be taken when selecting seals for canister 10 that such seals do not outgas, even though such seals may provide an otherwise adequate seal. Outgassing of seals can be the source of unwanted reactions within canister 10, yielding erroneous data.

When electrode 40 is the anode, a glow discharge condition is maintained by connecting cylindrical metal wall 30 to a negative voltage at terminal 30 such that coating 14 comprises an anode-facing surface of a cathode. As such coating 14

operates as an FLM cathode. During a cleaning cycle, discharge is maintained within a sputtering pressure of 10 mTorr. During such sputtering operation, material is sputtered from cathode surface 14 to be redeposited upon electrode 40 (while acting as the anode). In this manner, the surface 14 is atomically cleaned of surface deposits.

5 After the cleaning procedure voltage is removed from the electrodes 14,40 to turn of the discharge. An inert gas (preferably 99.9999% pure Argon) is administered through port 80 until a positive pressure above ambient atmospheric pressure can be maintained while electrode 40 is removed. To remove anode deposited contaminants, electrode 40 is physically extracted from canister 10 while the gas continues to blow
10 from the canister. In this manner, any atmospheric contaminants are kept from entering canister 10 to avoid the possibility of producing unwanted oxides, carbonates, sulphides or any other corrosive activity in the reactor.

While the inert gas continues to expire from canister 10, a new, clean electrode 40 is inserted into the chamber. Note that the new electrode 40 may have the same
15 surface material as cathode surface 14. Once electrode 40 is in place and access ports 42a and 42b are again sealed, a gas exchange is made through ports 80 and 90 seen in Figure 1 while maintaining an above ambient pressure in canister 10.

Note, that, under control of computer 210 seen in Figure 2, noble gas is steered into canister 10 under control of valve 240 while other mixtures of FE gases are
20 directed into canister 10 via FE gas administration system 252. To establish conditions for glow discharge, gas mixtures and pressures are introduced into canister 10 as described heretofore.

Prior, during and after each gas discharge, measurements may be made concerning thermal changes within canister 10 via heat exchange 345 and heat
25 exchangers 310 and 320. Other critical measurements may be made under control of computer 210 via one or more measurement system of the available testing systems comprising liquid scintillation counter 350, optical pyrometer 352, neutron spectrometer 353, gamma ray spectrometer 354, blankets 380, and mass spectrometer 351.

30 If optical energy photons are desired to be measured, wall 30 of canister 10 may be fitted with an optical window port 1200 as seen in Figure 12. One or more of

such ports may be installed into wall 30 to permit visual monitoring and measurement. Such ports are well known in the vacuum chamber art and generally comprise an exiting tube 1202 which is inserted into a close fitting hole 1204 in wall 30. At an end 1206, which is distal from wall 30, exiting tube 1202 comprises a

flange 1208 and an o-ring gasket partially disposed in a circular groove 1212. Generally flange 1208 is made to conform to a standard connecting flange specification, such as the connecting specification for NW50 flange of HPS Division of MKS Instruments, Boulder Colorado. Tube 1202 is preferably firmly and sealably affixed to wall 30 by a weldment 1214. Similar releasible attachment equipment capable of withstand sealing requirements of canister 10 is found in the Encyclopedia of Materials Characterization, published by Butterworth Heinemon of Boston, Mass., copyright 1992.

As one who is skilled in the glow discharge art well understands, canister 10 may be used to test higher current densities measured in amperes per unit cathode surface area. Such current densities may be in excess of current generally permitted in normal glow discharge. By using a pulsed laser power supply as power supply 220, a short duration pulse of hundreds of thousands of amperes may be driven between anode and cathode. Under such conditions, if the cathode and anode surfaces are free of contaminants, very high current densities may be achieved per unit area of cathode surface before the reactor is driven into an arc mode. Such operation may be useful in exciting different FE "wind" speeds within the FLM as described by Wipf et al. and chapter 7 in Hydrogen in Metals II, Publ. Springer-Verlag, Eds. G. Alefeld, J. Volkl, 1978. Application of such high currents allows testing of high electrical gradient effects upon FLM coating surfaces. Such effects may evidence high, but short duration thermal gradients in the FLM surface. Of course, current and voltages should be continuously monitored during all phases of operation to provide a thorough data background for each test.

Temperature of an FLM surface of electrode 14 when used as a cathode may be monitored by shutting off the glow discharge. If electrode 40 (used as the anode in this circumstance) is a relatively thin wire compared to the mass of electrode 14, the anode will rapidly come into thermal equilibrium with wall 30 (surface 40) by virtue

of black body radiation. At such equilibrium, if a known current (e.g. 10 milliamperes) is conducted along electrode 40, the resistance of surface 14 is a function of wire resistance. By precalibrating electrode 40 as a function resistance vs. temperature, a quick and accurate measurement of internal canister 10 temperature is determined.

Note that if electrode 40 is hollow, as seen in Figure 13, water may be conducted therethrough to carry off heat from canister 10 during operation. It should be emphasized that use of hollow electrode 40 as an opportunity for transmission of water is for the purpose of example only and that the hollow of electrode 40 may be used for quite different purposes. Such a hollow electrode, designated as 40' in Figure 13, may contain a tightly wound coil 1220 of conductive wire, similar to a solenoid coil.

As seen in Figure 13, electrode 40' is attached to terminal 50 through a connecting wire 1222. Connecting wire 1222 is connected to electrode 40' only at end 1224. Connecting wire 1222 is also connected to coil 1220 and therethrough to terminal 60. Conduction of current through coil 1220 provides a magnetic field of axial nature along cathode 41' and/or anode surfaces. Such a magnetic field is useful in increasing cleaning rates during discharge cleaning as activation of the magnetic field creates a Thornton cylindrical magnetron. (See U.S. Patents by J.A. Thornton.) If a constant current glow discharge is in process, increasing the field in coil 1220 has the effect of dropping the operational voltage within canister 10. Thus, the mean energy of the particles bombarding cathode 1220 is changed without changing other control parameters, such as gas pressure, gas composition, cathode current density, etc., within canister 10. Note that computer 210 may be programmed to maintain constant power input while changing the magnetic field in value such that temperature of cathode 41' (the FLM metal) stays constant.

As the purpose of the reactor is to test for nuclear reactions, it should be recognized that evidence of nuclear products should be researched before, during and after operation of the reactor. Should a nuclear reaction occur, products of such reactions may be found in the FLM metal after reactor operation. To test for products of a nuclear reaction, an axial magnetic field is actuated in coil 1220 to sputter clean

the cathode. Note that the cathode may be electrode 40' or surface 14. Any detectable gaseous nuclear products are thus removable from FLM material by sputtering and further removed from canister 10 as atomic vapor as gaseous products (such as He³, He⁴, H³ (tritium) or other light gases). By measuring gas quantities and isotopic ratios of canister 10 gases before and after operation, evidence of nuclear reaction may be determined. Special attention should be paid to nuclear shifts in isotopic ratios. Note that such gases are accessible through line 272 as earlier disclosed.

Further, disposing optical window 1200 in line of a site of discharge cleaning provides access for measurement of sputter removed gases by a mass spectrometer.

Note that such sputtering allows similar measurement during or after testing.

Sputtering also permits deposition of FLM material from one electrode, such as electrode 40 to another electrode, such as to surface 14. By the non-contaminating method of electrode 40 replacement disclosed previously, FLM metal at surface 14 can be kept almost atomically clean and cathodes of almost any electrically conductive compound alloy or element can be introduced into canister 10 through ports 42a and 42b. As an example, sputtering of electrode 40 permits deposition of any desired FLM material onto surface 14, or vice versa. By controlling time of sputtering and other sputtering parameters known in the art, any sputterable material in any desired thickness can be deposited upon surface 14 for use in subsequent operation and testing. In the same manner thin coats of barrier material which is impervious to low energy hydrogen isotopes may be added to surface 14. Such thin coats may be used to seal hydrogen into the FLM material on surface 14. As an example, it is well known in the art that a deposition of aluminum of 10-100 angstroms thick will provide such a seal.

Noble gases used in sputtering from vessel 242 or from a combination of vessels comprising a controllable mixer, such as gas administration system 252 used in this case for the administration of noble gases under control of computer 210, may be delivered with different isotopic compositions. As examples, Helium may be delivered with a known ration of He³ and He⁴ or Xenon in ratios of Xenon(y):Xenon(x). Where "y" and "x" are isotopic indicators.

Further, canister 10 may be used as an ejected neutral or charged particle spectrometer. In this mode of use, canister 10 is employed as a proportional, ionization or Geiger counter. The need and usefulness of canister 10 in such an application is made manifest by a report by Karabut et al. titled "Nuclear Product
5 Ratio for Glow Discharge in Deuterium" published in Physics Letters A (1992), pp 265-272, wherein Karabut et al. report that emission of energetic charged particle have been detected for extended periods of time (hours) after turning off glow discharge on a palladium FLM. Energies of such charged particles can be measured by running canister 10 in a proportional counter mode which is accomplished by
10 turning off a plasma discharge and rapidly pumping or increasing gas pressure and mixture in canister 10 to pressures which best support proportional counter operation. In this mode, the central electrode should be a thin wire (about one mil in diameter) and made of tungsten or other relatively stable metal. Surface 14 would have been the cathode.

15 Such proportional counters are well known in the art nuclear detection art. All mechanical elements required for fabrication of such a counter are seen in Figure 1. All of the necessary gas filling elements are seen in Figure 2. All necessary control is provided by computer 210. Proportional counting may be accomplished under noble gas atmospheres, hydrogen atmospheres or by administration of P-10 gas (argon with
20 a trace of methane). High voltage supply 220 connected to computer 210 by control line e provides a regulated high voltage on the order of 100-2000 volts. The number and amount of current in each recorded pulse is delivered to computer 210. Each particle emitted from surface 14 into canister 10 produces a distinct number of charges which may be measured by current sensing device 300, seen in Figure 3.
25 Very importantly, energy spectra should also be measured and recorded in computer 210.

30 Scintillation counter 350, also seen in Figure 3, may be used as a beta particle measuring device. By connecting counter 350 in direct line of sight into canister 10, beta emissions from surface 14 may be detected while canister 10 is under a high vacuum.

Regarding temperature control, heater 230, seen in Figure 2, may be applied anywhere on the surface of canister 10, as one who is skilled in the art of heat transmission well understands. Active elements within heater 230 may be peltier devices which are widely known and available in the heat and temperature art. By reversing current on peltier devices, cooling may be provided to canister 10 as well as heat. In this fashion, a bulk temperature of canister 10 as well as a reflected temperature to the FLM of electrode 40' can be controllably altered by computer 210. In this manner, an adjustable temperature is provided, allowing temperature to ramped up or down at a predetermined rate or to maintain temperature at a desired level. As computer 210 also receives values of canister 10 pressure, applied cathode current, gas mixture, and other measured parameters, temperature control may be varied under control of computer 210 as a function of combinations of the measured parameters.

For careful calorimetry measurements, absorption blankets 380 (disposed as shown in Figure 3) should be made of highly insulating material. Feedback thermocouples or other well calibrated and sensitive temperature measuring devices are disposed into inlet and outlet pipes 335 and 340. Energy is removed using heat exchanger 340 and any thermal gain is calculated consistent with good calorimetry practice.

Heretofore, it was noted that electrode 40 and surface 14 could be interchanged relative to use as either an anode or cathode by simply reversing electrode polarities. In all cases, the cathode should comprise at least an anode-facing covering of FLM, unless the reason for reversal of electrode polarities is for the purpose of cleaning. In all cases of use, cathode resistance should be used to determine FLM loading.

Another embodiment employing multiple electrode pairs similar to the embodiment of Figure 6 is seen in Figure 14. The reactor of Figure 14 comprises a cylindrical canister 10' which is similar to canister 10, a fluid space 1230 and three electrode pairs 1232, 1234 and 1236. Each electrode pair 1232, 1234 and 1246 comprises a hollow cylindrical tube 1240 preferably made from copper or another metal which exhibits a high heat transfer and a low hydrogen mobility. A thin layer 1242 of FLM material is deposited on each inner surface 1244 of each tube 1240 and

a coaxial electrode 1246 (anode) made of relative inert, high melting temperature metal such as tungsten is centrally disposed through the hollow of each tube 1240.

Space 1250 between electrode 1246 and layer 1242 is filled with a gas from a gas source in a manner described for gas administration system 252. Electrode operation is cycled as described above for electrodes 601, 602 and 603. However, in this case space 1230 is filled with a heat absorbing fluid which acts as a coolant and, if necessary, a neutron moderator to carry energy produced by-products from canister 10'. It should be noted that tube 1240 may be made from FLM material.

Deposition of electrically conductive sputtered film upon the inner canister surfaces of hermetically sealed caps 20 (i.e. 20a and 20b) which are purposely made of vacuum compatible machinable high-temperature ceramic to be non-conductive to act as a containment for glow discharge, can dramatically reduce the useful life of canister 10. See Figures 1, 12 and 13. To reduce such deposition upon caps 20, a shield 1260a is disposed over the inner surface of 20a and a shield 1260b is disposed over the inner surface of 20b as seen in Figure 12. Of course such shields 1260a and 1260b may be used in any of the embodiments of the invention to reduce unwanted deposition and extend useful reactor life.

Each shield 1260a and 1260b is generally of a disk shape and comprises an interior facing surface 1262, a cap facing surface 1264 and an outer rim 1265. Extending from surface 1264 and lying within a shadow of glow discharge within canister 10 is a ring or a group of feet 1266. Offset resulting from ring or feet 1266 combined with a disk size which assures that rim 1265 does not contact or become contaminated and thereby contact wall 30 significantly reduces any likelihood that by-product deposition will create a conductance path which will change the character of glow discharge in canister 10. To improve the shadow effect of each shield 1260a and 1260b, a centrally disposed hollow stem 1270 is extended inwardly about but not in electrical contact with electrode 40. Each shield 1260a and 1260b is mechanically affixed to each cap 20a and 20b, respectively at feet or ring 1266. Shields 1260a and 1260b are preferably made from the same material used in manufacture of caps 20a and 20b.

Further, it is to be expressly understood that the claimed inventions are not to be limited to the description of the preferred embodiment but encompasses other modifications and alterations within the scope and spirit of the inventive concept.

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CLAIMS

1. A system for testing methods and reactions related to cold fusion processes, said system comprising:

a canister (10) having a hermetically sealed formed chamber (12);
at least one cathode in said canister, said at least one cathode
5 comprising a fusion lattice metal (FLM);
at least one anode in said canister;
a gas, said gas comprising at least one fusion element (FE);
means connected to said canister for delivering said gas into said
canister at a predetermined pressure;
10 means connected to said at least one cathode and to said at least one
anode for providing a sufficient current density to obtain and maintain a glow
discharge condition, said discharge being achieved at said predetermined pressure and
said current density;
means in communication with said canister and parts therein for
15 monitoring for nuclear reaction by-products.

2. The system of Claim 1 wherein said providing means obtains highest
efficiencies when operating at current densities sufficient to obtain and maintain an
abnormal glow discharge condition.

3. The system of Claim 1 wherein said formed chamber comprises:
an outer cylinder (30) comprising said at least one anode;
a pair of insulating caps (20) located on opposing ends of said cylinder,
said at least one cathode comprising a single cathode (40) disposed in the center of
said cylinder so as to form a coaxial relationship with said anode.

4. The system of Claim 3 wherein said cathode is a cylindrical wire stretched
between said opposing caps.

5. The system of Claim 4 wherein said wire has a diameter in the range of
0.001 inch to 1 inch.

6. The system of Claim 3 wherein said outer cylinder comprises a substrate material having an inner layer facing said chamber composed of fusion lattice metal.

7. The system of Claim 6 wherein said inner layer is a coating of fusion lattice metal on said substrate material.

8. The system of Claim 1 wherein said chamber is capable of withstanding internal pressures of 0.01 microns to 10 atmospheres.

9. The system of Claim 1 further comprising a shield within said chamber to capture conductive particles emitted from anode and cathode operation and thereby shield insulating surfaces from becoming coated with conductive materials.

10. A method for cleaning operating parts of a gaseous reactor having as operating parts a cathode of fusion lattice metal and an anode disposed in a chamber, said method comprising the steps of:

pumping said chamber to a high vacuum;

applying power to said cathode in order to heat said cathode for a first predetermined time interval while said chamber is in said high vacuum to remove adsorbed surface atoms;

heating the interior walls of said chamber to boil off adsorbed gases for a second predetermined time interval while said chamber is in said high vacuum.

11. The method of Claim 10 wherein said step of pumping pumps said chamber to a vacuum in the range of 10^{-8} to 10^{-10} torr.

12. The method of Claim 10 wherein said step applying power to said cathode heats said cathode red to white hot in said first time interval of 5 to 10 minutes.

13. The method of Claim 12 wherein said step of applying power to said cathode further comprises the step of sensing the temperature of said cathode to provide feedback control to precisely control said temperature.

5 14. The method of Claim 10 wherein said step of heating heats said chamber in the range of 250°C to 300°C for the second time interval of 30 minutes to 2 hours.

10 15. The method of Claim 10 further comprising the additional steps of:
circulating a noble gas into said chamber at a predetermined pressure
in response to said steps of pumping, applying power to said cathode, and heating;
alternately sputtering off a predetermined amount of the surface of said
cathode and of said anode through selective application of a high power first to said
anode and then to said cathode.

15 16. The method of Claim 15 in which said predetermined pressure of said circulated noble gas is in the range of one to 20 millitorr.

20 17. The method of Claim 15 wherein said applied high power is in the current density range of 1 ma/cm² to 50 ma/cm² of surface area when said cathode is palladium.

18. The method of Claim 15 wherein said predetermined amount of surface sputtered off is 50-500 Angstroms when said surface is palladium.

25 19. The method of Claim 15 wherein simultaneous with said step of sputtering, the following step occurs:
generating a magnetic field around the cathode 40' to increase said sputtering.

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20. The method of Claim 15 further comprising the steps of:

filling said chamber with at least one type of hydrogen gas of a predetermined rate of purity to a predetermined pressure;

applying said high power to said cathode and said anode such that the first predetermined time is sufficient to obtain a predetermined solubility of atoms of hydrogen per atom of fusion metal lattice in said cathode;

reversing the polarity of said high power to said cathode to deplete said hydrogen from said cathode until the R/R₀ ratio of said cathode equals 0.5 - 1.0.

21. The method of Claim 20 wherein said predetermined hydrogen pressure is in the range of 10 millitorr to 10mm (of Hg).

22. The method of Claim 20 wherein said at least type of hydrogen gas is filtered to obtain a purity of greater than 99.999% before said step of filling.

23. The method of Claim 20 wherein said predetermined solubility is at least 0.74 for a palladium cathode.

24. A method of testing for cold fusion by-products in a gaseous reactor having a cathode of fusion lattice metal and an anode disposed in a chamber, said method comprising the steps of:

repeatedly and controllably cleaning said parts of said reactor of impurities during reactor operation, especially parts comprising said cathode and said anode;

delivering pressurized gas composing one or more fusion elements into said chamber;

applying power across said anode and said cathode to achieve glow discharge with a predetermined current density on the surface of said cathode; and

maintaining said pressure and said current density to sustain said

discharge;

monitoring for said by-products.

25. The method of Claim 24 wherein said cathode is formed from palladium material and said pressure of said delivered gas is set between 10 mtorr and 10 mm (of Hg) for palladium.

5 26. The method of Claim 24 wherein said cathode is formed from palladium material and said current density is 1.2ma/cm² at 200 volts for palladium.

10 27. The method of Claim 24 further comprising the step of monitoring the R/R_o characteristic of said cathode for the time interval commencing with the application of said power to the occurrence of said cold fusion.

28. The method of Claim 24 wherein the delivered gas is recirculated through said chamber.

15 29. The method of Claim 24 further comprising the steps of:
periodically shutting off said power supply in order to leak out said gas from said cathode;
determining the presence of specific fusion by-products in said leaked out gas.

20 30. A system for obtaining nuclear fusion, said system comprising:
a chamber;
three electrodes in said chamber, each of said electrodes comprising a fusion lattice metal;
25 a gas, said gas comprising at least one fusion element;
means receptive of said gas for delivering said gas into said chamber at a predetermined pressure;
means connected to said three electrodes for selectively applying a
predetermined current density to said three electrodes in the following fashion:

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Time	Time	Time	Time
1	2	3	4

Electrodes

5	601	Cathode	Anode Idler	Cathode
	602	Anode Idler	Cathode	Anode
	603	Idler	Cathode	Anode Idler

10 said connected means providing sufficient power to the electrode selected as cathode to obtain and maintain a glow discharge condition for said selected cathode until said fusion is achieved.

31. The system of Claim 30 further comprising:
a canister, said canister being cylindrically shaped with said three
15 electrodes being placed therein.

32. The system of Claim 30 wherein each of said three electrodes comprises:
an elongated tube of substrate metal, each said tube having a formed
inner space therein extending the length of said tube.

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33. The system of Claim 32 wherein said fusion metal lattice is bonded as a coating onto the outer surface of said substrate metal.

25 34. A test system for experimenting on cold nuclear fusion and related nuclear reactions, said system comprising:

a chamber;
three electrodes in said chamber, each of said electrodes comprising a fusion lattice metal;
a gas, said gas comprising at least one fusion element;
30 means receptive of said gas for delivering said gas into said chamber at a predetermined pressure;

means connected to said three electrodes for selectively applying a predetermined current density to said three electrodes in the following fashion:

	Time	Time	Time	Time
	1	2	3	4
<hr/>				
<u>Electrodes</u>				
601	Cathode	Anode Idler	Cathode	
602	Anode Idler	Cathode	Anode	
603	Idler	Cathode	Anode Idler	

said connected means providing sufficient power to the electrode selected as cathode to obtain and maintain a glow discharge condition for said selected cathode until said fusion is achieved.

35. The system of Claim 34 further comprising:
a canister, said canister being cylindrically shaped with said three electrodes being placed therein.

36. The system of Claim 34 wherein each of said three electrodes comprises:
an elongated tube of substrate metal, each said tube having a formed inner space therein extending the length of said tube.

37. The system of Claim 36 wherein said fusion metal lattice is bonded as a coating onto the outer surface of said substrate metal.

38. A system for obtaining cold nuclear reactions, said system comprising:
a canister (10) having a hermetically sealed formed chamber (12);
at least one cathode in said canister; said at least one cathode comprising a fusion lattice metal (FLM);
at least one anode in said canister;
a gas, said gas comprising at least one fusion element (FE);

means connected to said canister for delivering said gas into said canister at a predetermined pressure;

means connected to said at least cathode and to said at least one anode for providing a sufficient current density to said cathode to obtain and maintain a glow discharge condition for said at least one cathode, said fusion being achieved at said predetermined pressure and said current density.

39. The system of Claim 38 wherein said providing means obtains highest efficiencies when operating at current densities sufficient to obtain and maintain an abnormal glow discharge condition.

40. The system of Claim 38 wherein said formed chamber comprises:
an outer cylinder (30) comprising said at least one anode;
a pair of insulating caps (20) located on opposing ends of said cylinder, said at least one cathode comprising a single cathode (40) disposed in the center of said cylinder so as to form a coaxial relationship with said anode.

41. The system of Claim 40 wherein said cathode is a cylindrical wire stretched between said opposing caps.

42. The system of Claim 41 wherein said wire has a diameter in the range of 0.001 inch to 1 inch.

43. The system of Claim 40 wherein said outer cylinder comprises a substrate material having an inner layer facing said chamber composed of fusion lattice metal.

44. The system of Claim 42 wherein said inner layer is a coating of fusion lattice metal on said substrate material.

45. The system of Claim 38 wherein said chamber is capable of withstanding internal pressures of 0.01 microns to 50 atmospheres.

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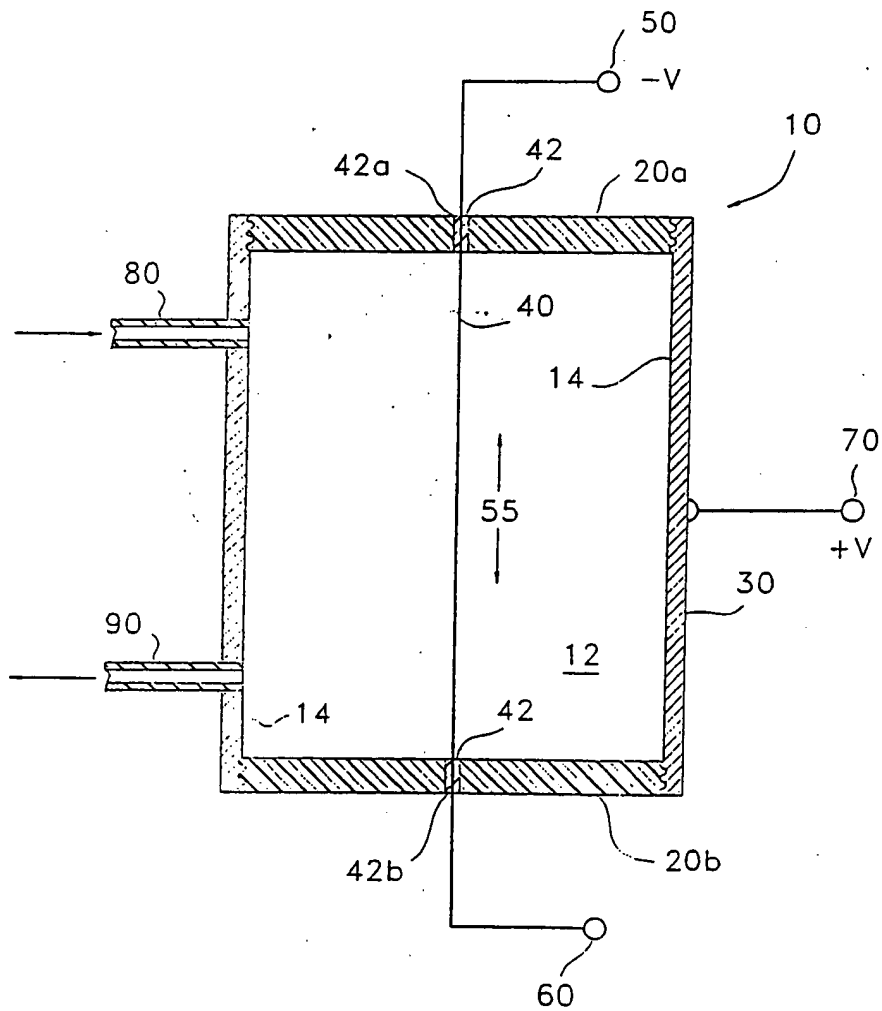


Fig. 1

SUBSTITUTE SHEET (RULE 26)

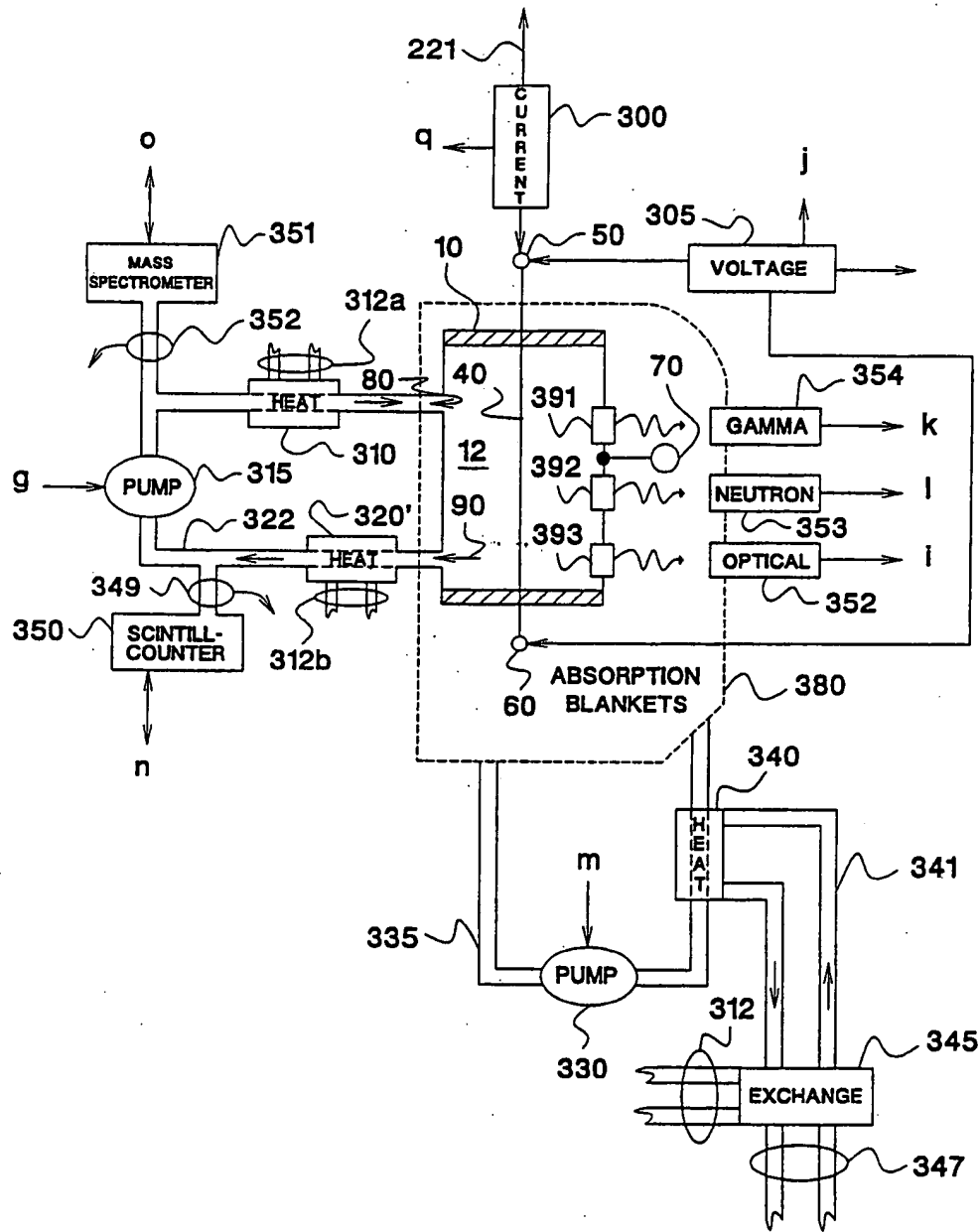


Figure 3

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Fig. 4

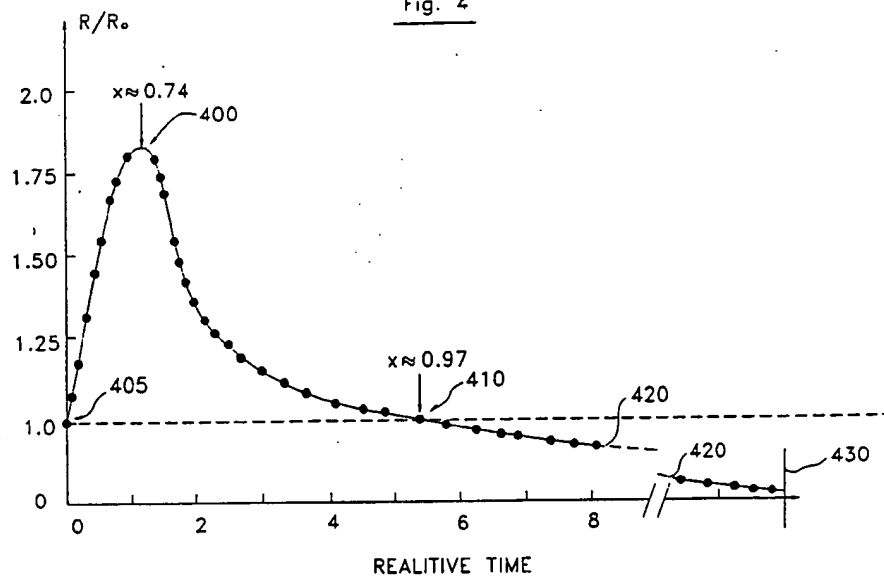
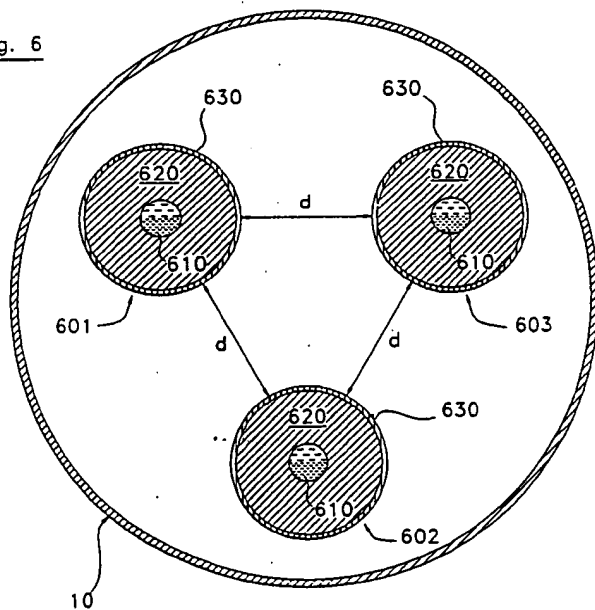


Fig. 6



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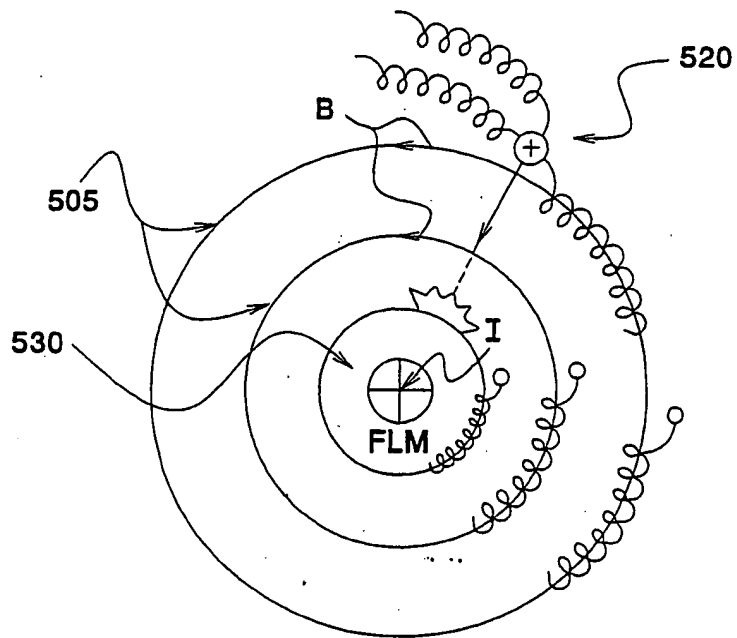


FIGURE 5a

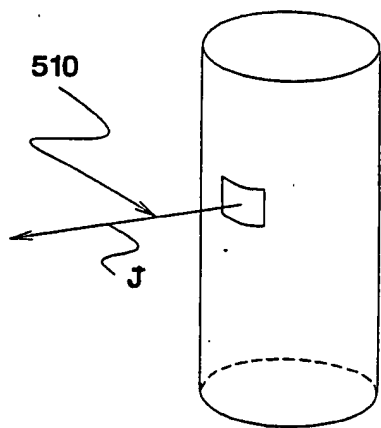


FIGURE 5b

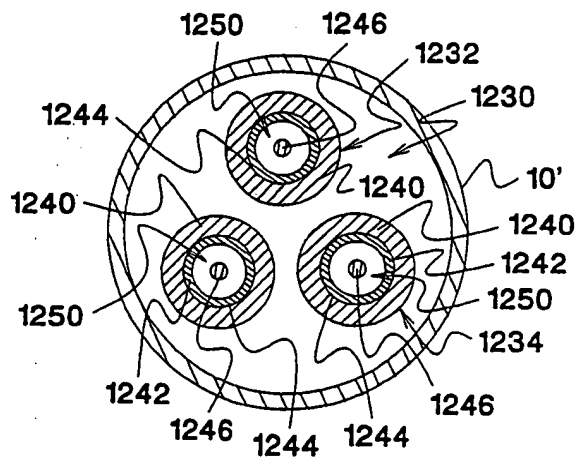


FIGURE 14

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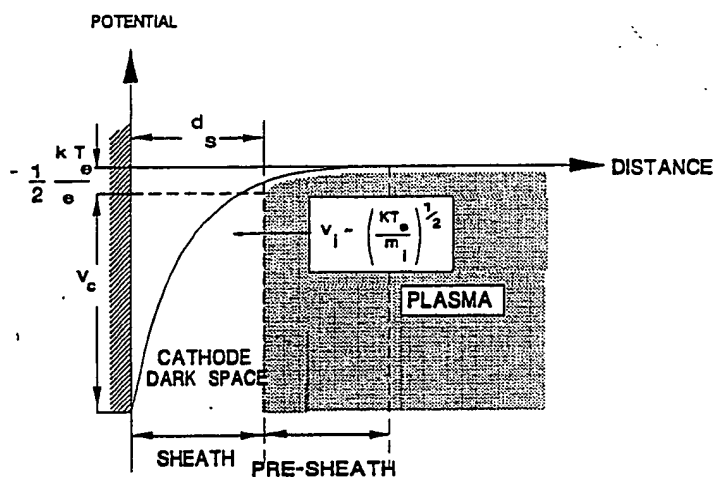


FIGURE 7a

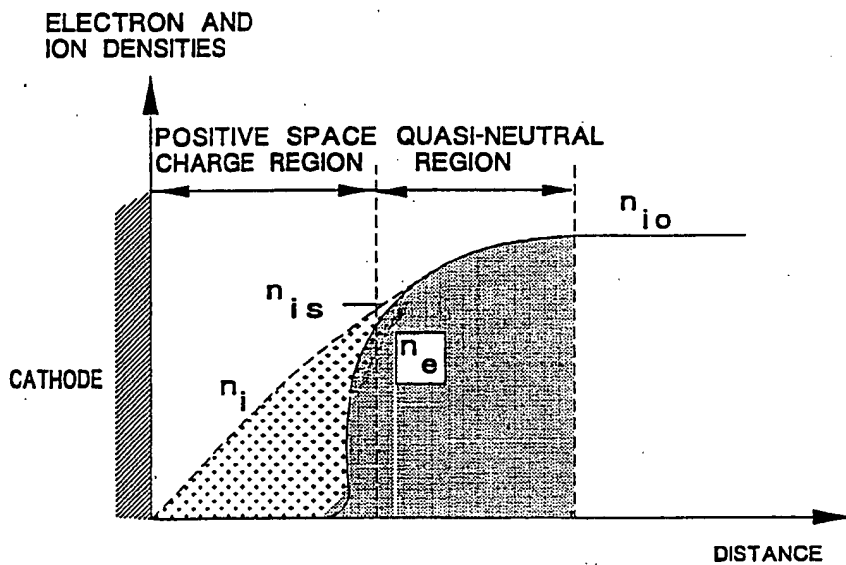


FIGURE 7b

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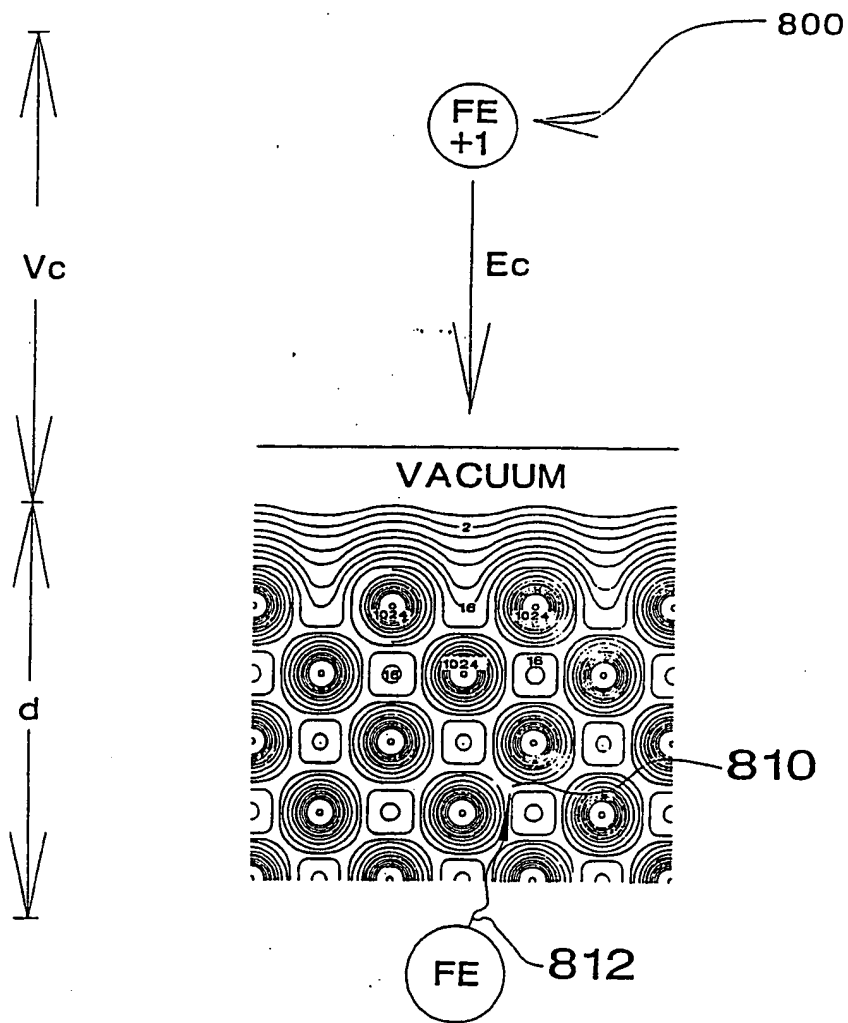


FIGURE 8

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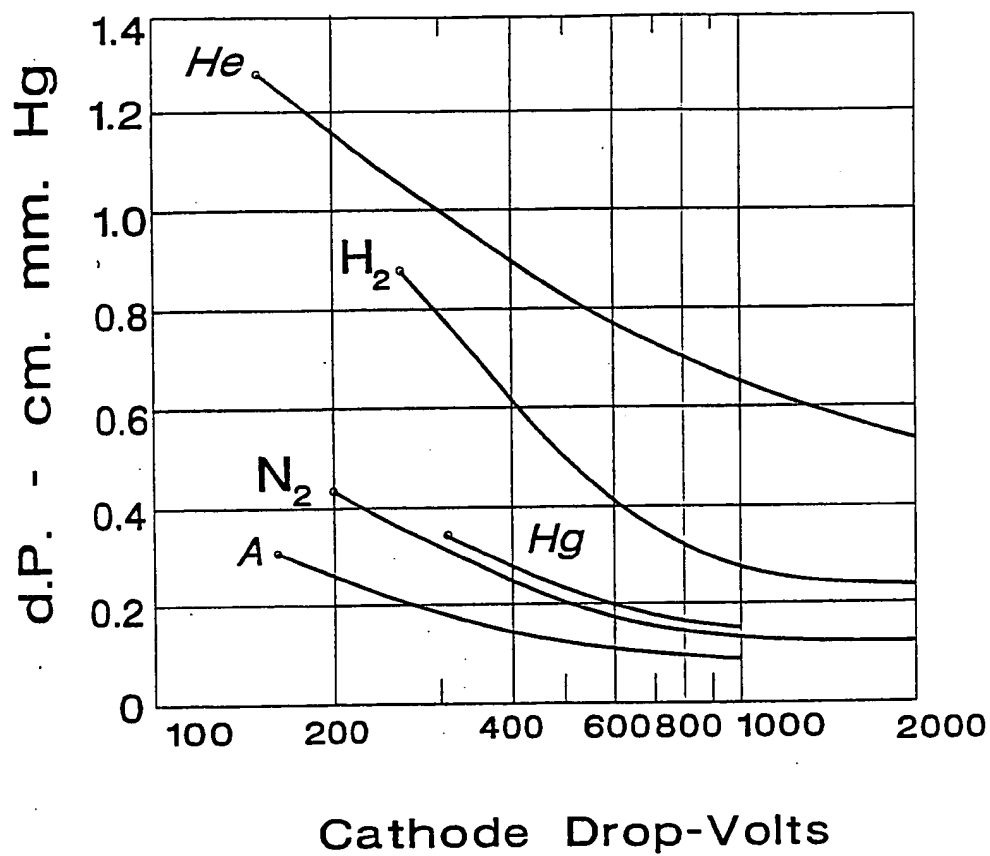


FIGURE 9

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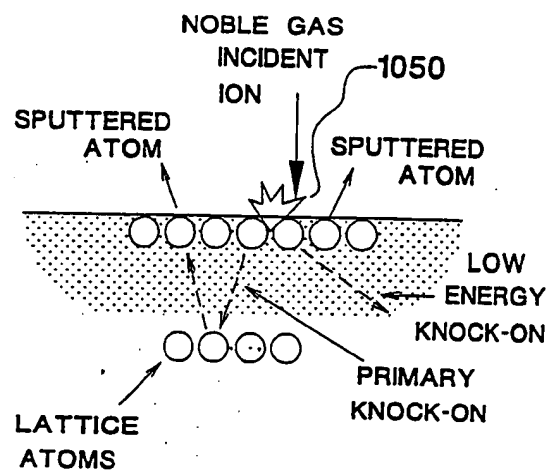


FIGURE 10

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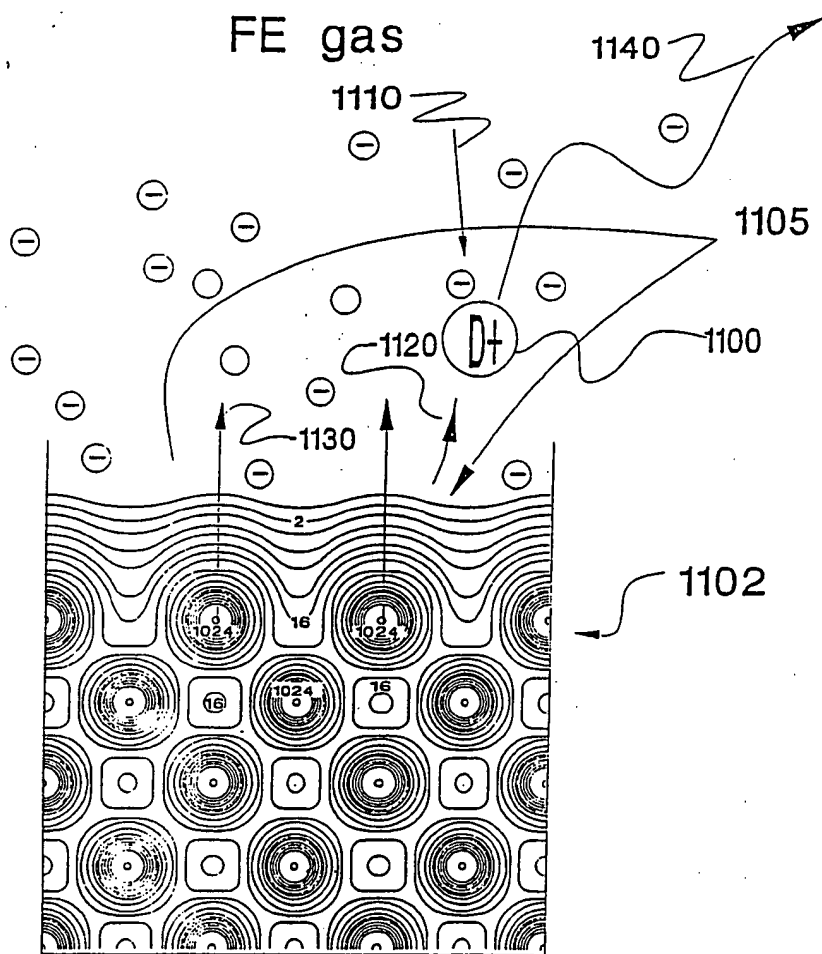


FIGURE 11

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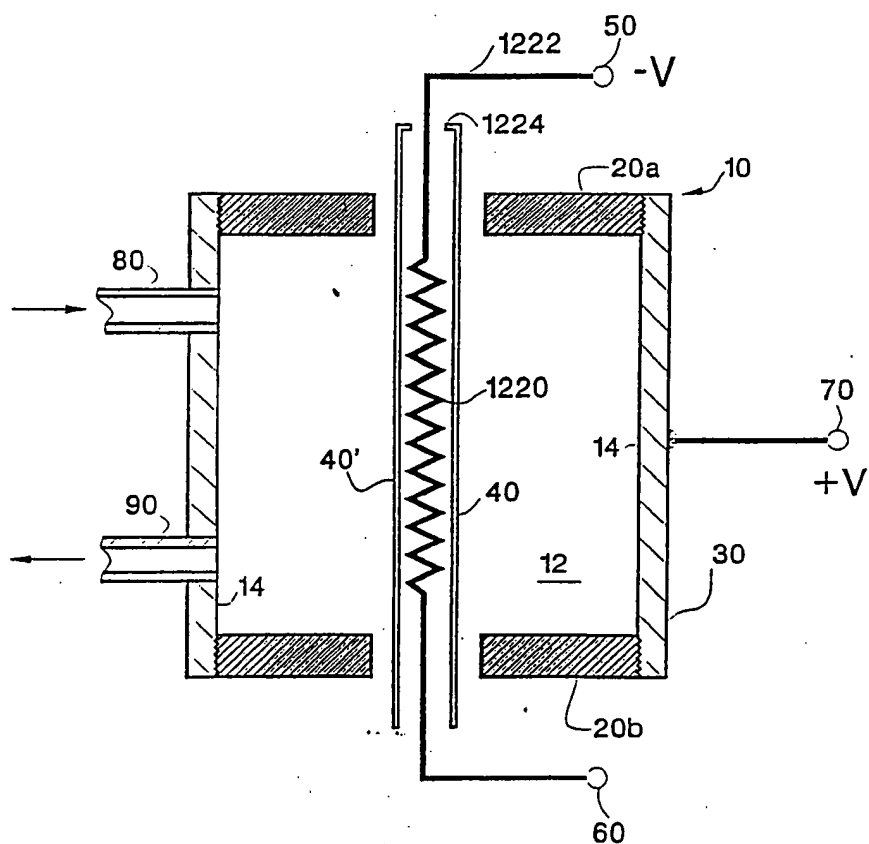


FIGURE 13

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INTERNATIONAL SEARCH REPORT

 tional application No.
PCT/US94/12519

A. CLASSIFICATION OF SUBJECT MATTER

 IPC(6) : G21B 1/00
US CL : 376/100

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : Please See Extra Sheet.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	WO, A, 92/08232 (HEREDY) 14 May 1992; note pages 13-14; figures 1-2.	1-2, 24, 28-29, 38-39 ----- 3-23, 25-27, 40-44
X --- Y	JP, A, 3-105284 (FUJITSU LTD) 02 May 1991; note the abstract.	38-39 ----- 1-29, 40-44
X --- Y	EP, A, 414399 (HASEGAWA ET AL.) 27 February 1991; note entire document; figures 1 and 5.	38-39 ----- 1-29, 40-44
X --- Y	US, A, 4,452,642 (DIETZ ET AL) 05 June 1984; note col. 1, lines 31-35; col. 3, lines 3-10; and col. 4, lines 8-51.	1, 38 ----- 2-9, 39-44

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

Special categories of cited documents:	
A document defining the general state of the art which is not considered to be part of particular relevance	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
E earlier document published on or after the international filing date	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
O document referring to an oral disclosure, use, exhibition or other means	*Z* document member of the same patent family
P document published prior to the international filing date but later than the priority date claimed	

 Date of the actual completion of the international search
24 FEBRUARY 1995

 Date of mailing of the international search report
20 MAR 1995

 Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
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Authorized officer

DANIEL WASIL

Telephone No. (703) 308-0442

Form PCT/ISA/210 (second sheet)(July 1992)*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/12519

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 3, 856, 647 (BLACHMAN) 24 December 1974; note col. 2, lines 27-33, 57-59; and col. 3, lines 17-25.	3, 11, 40
Y	US, A, 5,221,416 (KISHI ET AL) 22 June 1993; note col. 1, lines 61-68; figure 2.	3, 40
Y	US, A, 4,505,947 (VUKANOVIC ET AL) 19 March 1985; note col. 6, lines 3-9; figures 3-4.	3, 40
X	US, A, 3,572,875 (NOBLE) 30 March 1971; note col. 1 line 69 - col. 2, line 40.	10, 38-39
---		-----
Y		1-9, 11-29, 40-44
Y	US, A, 2,240,914 (SCHUTZE) 06 May 1941; note col. 1, lines 52-55; and col. 2, lines 23-24.	21, 25-26
Y	"The Transformation of Hydrogen into Helium" (PANETH ET AL) Berichte der Deutschen Chemischen Gesellschaft, August 1926, pp. 2039-2048; note translated pages 8-9.	24
Y	US, A, 3,569,756 (REIFENSCHWEILER) 09 March 1971; note col. 2, lines 18-22.	21, 25
Y	US, A, 3,746,859 (HILTON) 17 July 1973; note col. 3, lines 24-32.	26
Y	FLANAGAN "Hydrogen Absorption by Palladium in Aqueous Solution" vol. 55, pp. 1400-1408, August 1959, The Faraday Society, The Aberdeen University Press Ltd. 6 Upper Kirkgate, (Aberdeen Scotland); note pages 1400-1402.	27
A	US, A, 5,007,424 (AHSBAHS ET AL.) 16 April 1991; note entire document.	30-37
L	Journal of Fusion Energy, Vol. 9, No.3, September 1990, Myers et al. "Search for Cold Fusion at D/Pd > 1 Using Ion Implantation", pp. 263-268; cited as casting doubt on inducing nuclear fusion in a catalyst by forcing hydrogen isotopes therein.	1-44
L	TAUBES, Bad Science, "The Short Life and Weird Times of Cold Fusion" 1993, Random House (New York) pp. 303, 425-428, 475-481; note entire document.	1-44
L	C&EN (DAGANI) "New Cold Fusion Results Fail to Win Over Skeptics", 14 June 1993, pp. 38-41; note entire document.	1-44

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/12519

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Please See Extra Sheet.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
☒ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet(1))(July 1992)*

INTERNATIONAL SEARCH REPORT

tional application No.
PCT/US94/12519

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
L	HUIZENGA, Cold Fusion " The Scientific Fiasco of the Century", 1993, Oxford University Press (Oxford, New York Tokyo), pp. xii-xv, 22-41, 58-91, 128-189, 200-223, 285-287, 292-318; note entire document.	1-44

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INTERNATIONAL SEARCH REPORT

I. International application No.
PCT/US94/12519

B. FIELDS SEARCHED

Minimum documentation searched

Classification System: U.S. -

376/100, 108-119, 144-146;
204/129.35, 141.5, 164, 298.33

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING

This ISA found multiple inventions as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, claims 1-9 and 38-44, drawn to a system related to cold fusion including a hermetically sealed chamber.

Group II, claims 10-23, drawn to a method for cleaning a fusion lattice metal of a gaseous reactor.

Group III, claims 24-29, drawn to a method of testing for cold fusion by-products.

Group IV, claims 30-37, drawn to a system related to cold fusion including three electrodes.

The claims of the Groups are directed to different inventions which are not so linked as to form a single general inventive concept. Each invention lacks unity with each other invention because there is no common special technical feature which defines a contribution over the prior art. There is a lack of unity between the independent and distinct inventions. See PCT Rule 13.2.